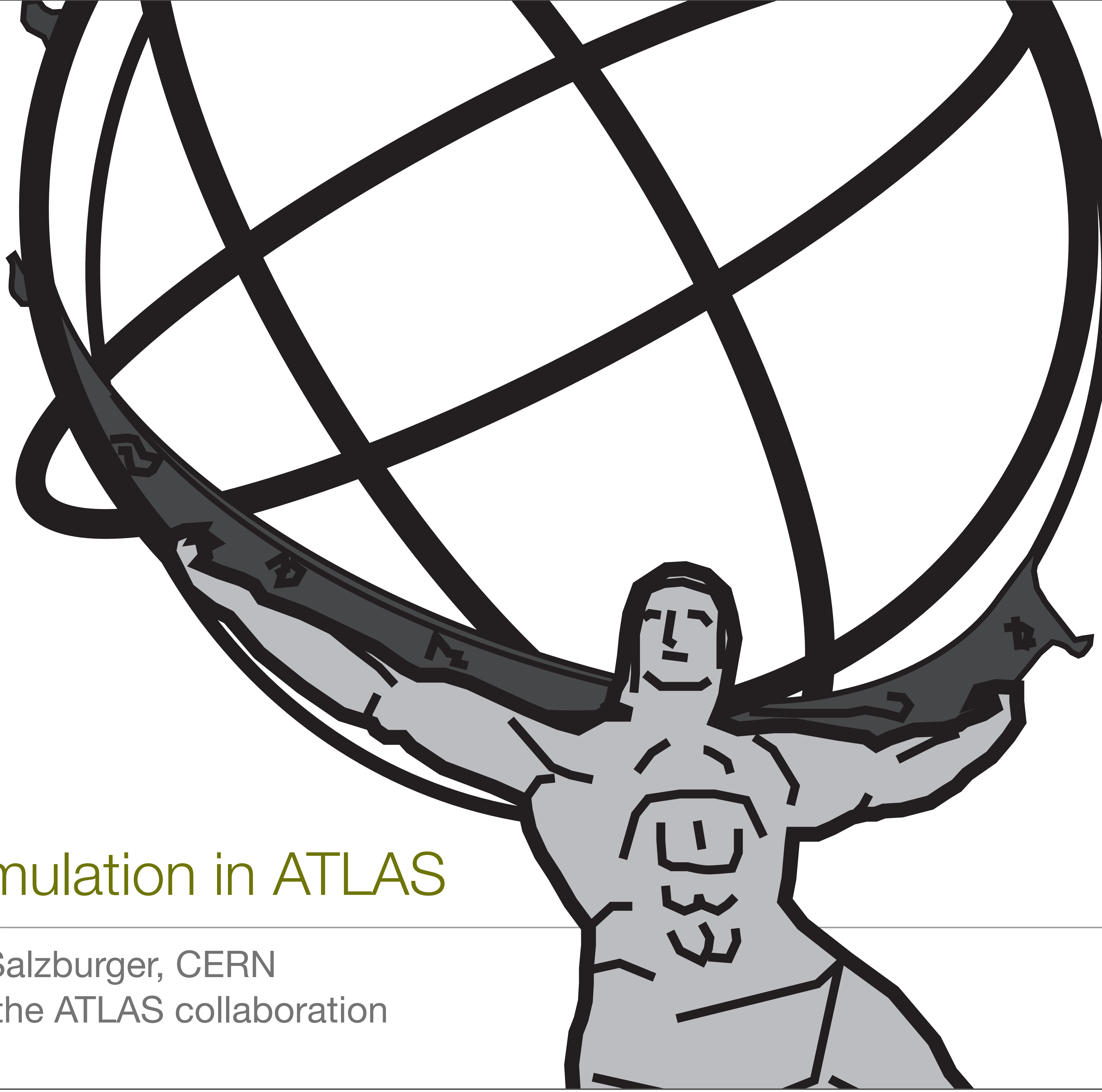


Fast simulation in ATLAS

A. Salzburger, CERN
for the ATLAS collaboration

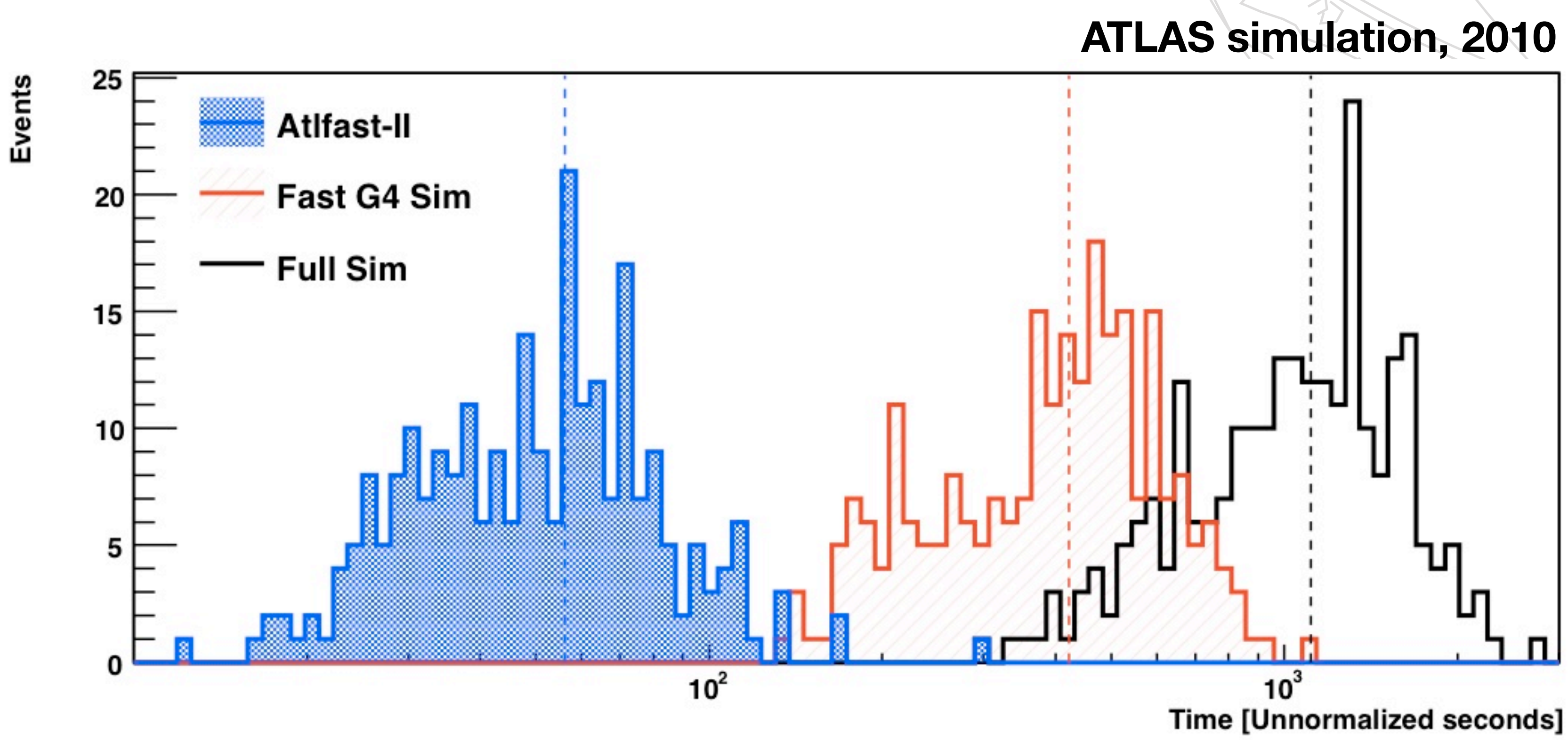
Simulation load & requirements

typical MC campaign in ATLAS 2011

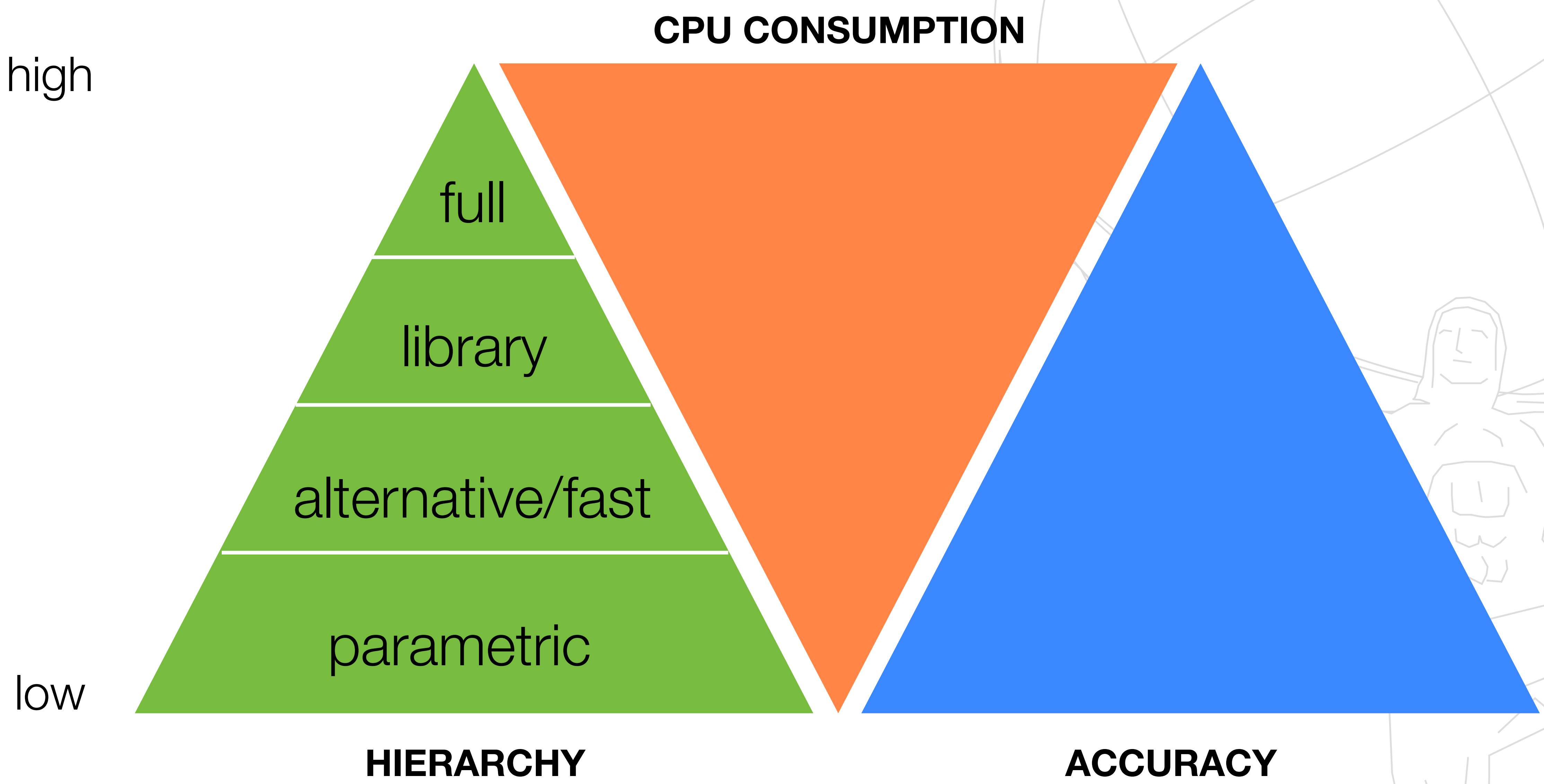
- *$O(10^9)$ events << recorded data*
- *future precision measurements will need more*

fast MC is needed to cope with present/future needs

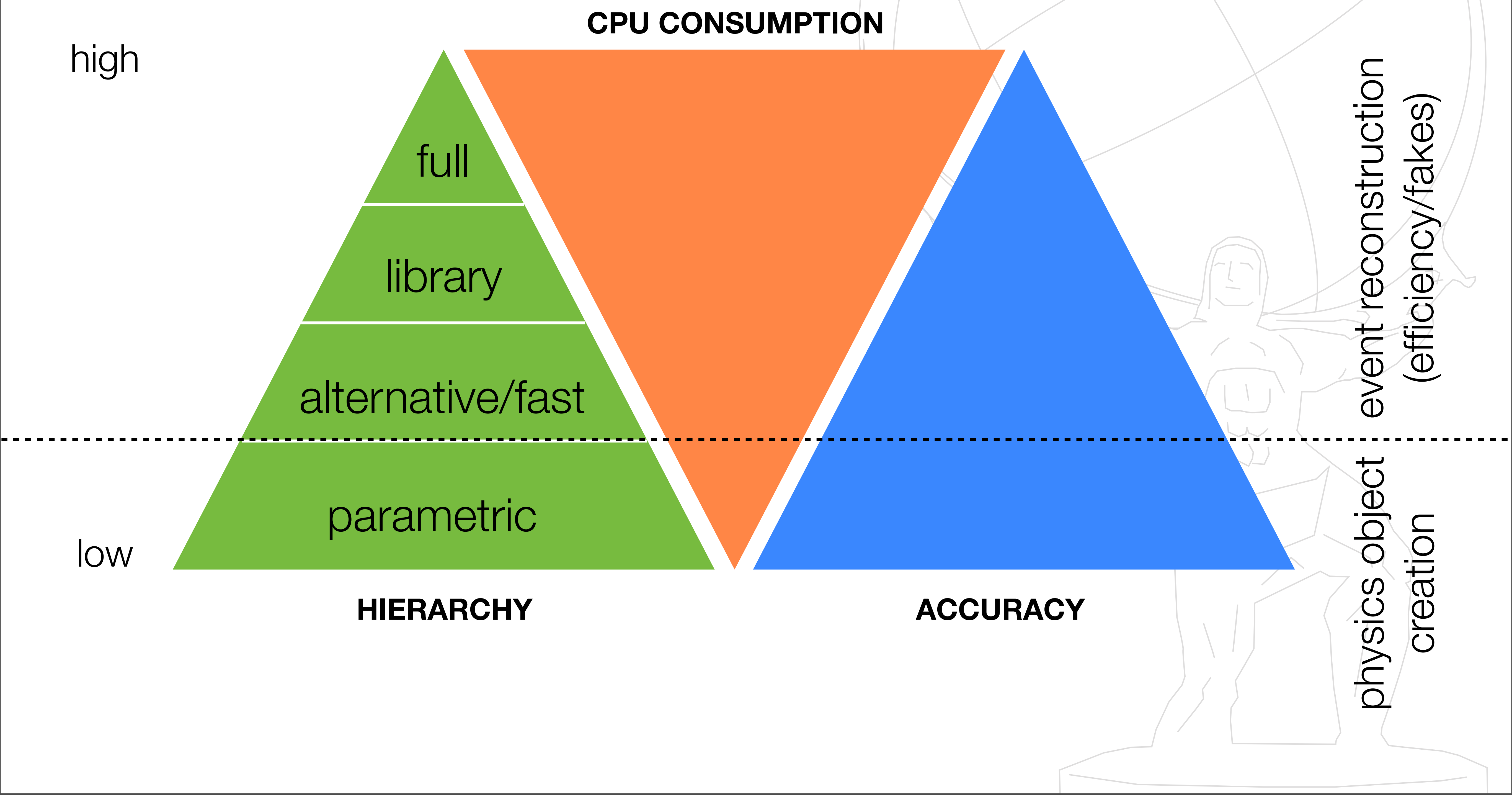
- *higher statistics raises additional questions: I/O, disk space, reconstruction time*
- *see talk of R. Brun on simulation R&D this afternoon*



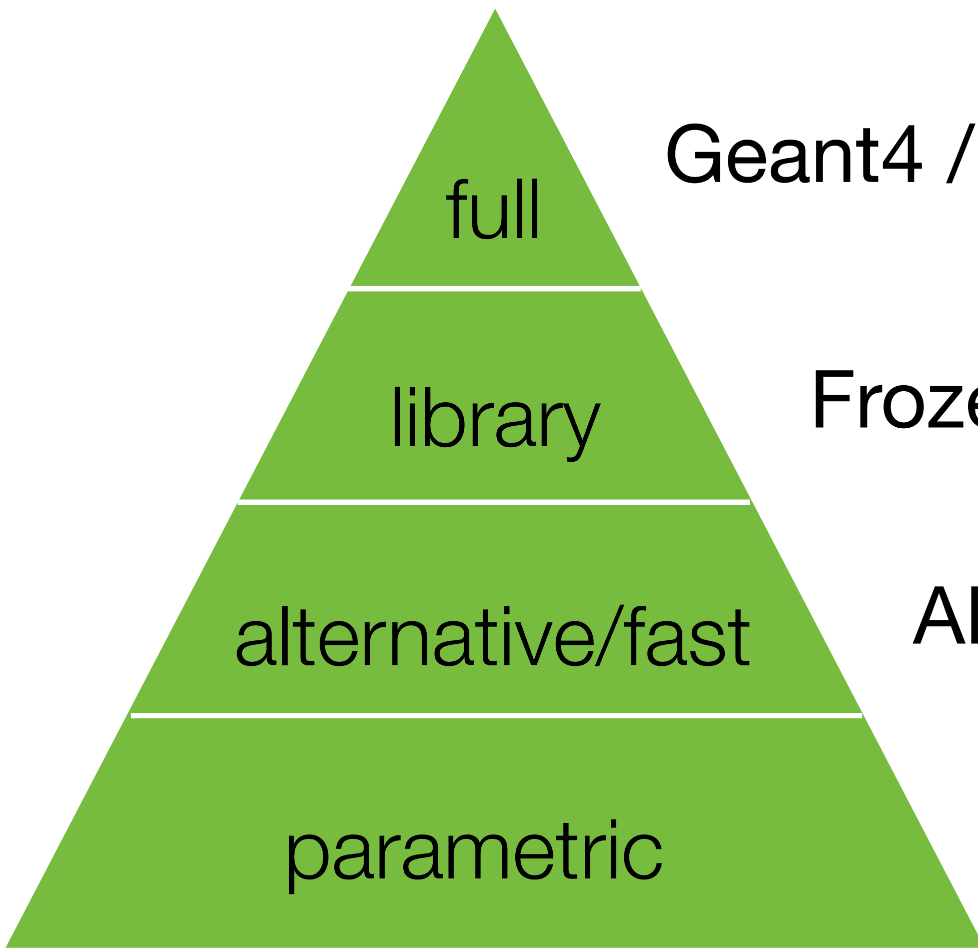
Simulation hierarchy



Simulation hierarchy



Simulation in ATLAS ❖ 20+ years of simulation



Geant4 / Fluka,Flugg / Geant3

Frozen Showers

AFII (Atlfast2) / AFIIF (Atlfast2F)

Atlfast(1)

Full Simulation ❖ Geant4

full

talk of J. Chapman

talks at this WS

geometry model: Geant4 (translated from ATLAS GeoModel), very detailed, $O(10^6)$ nodes

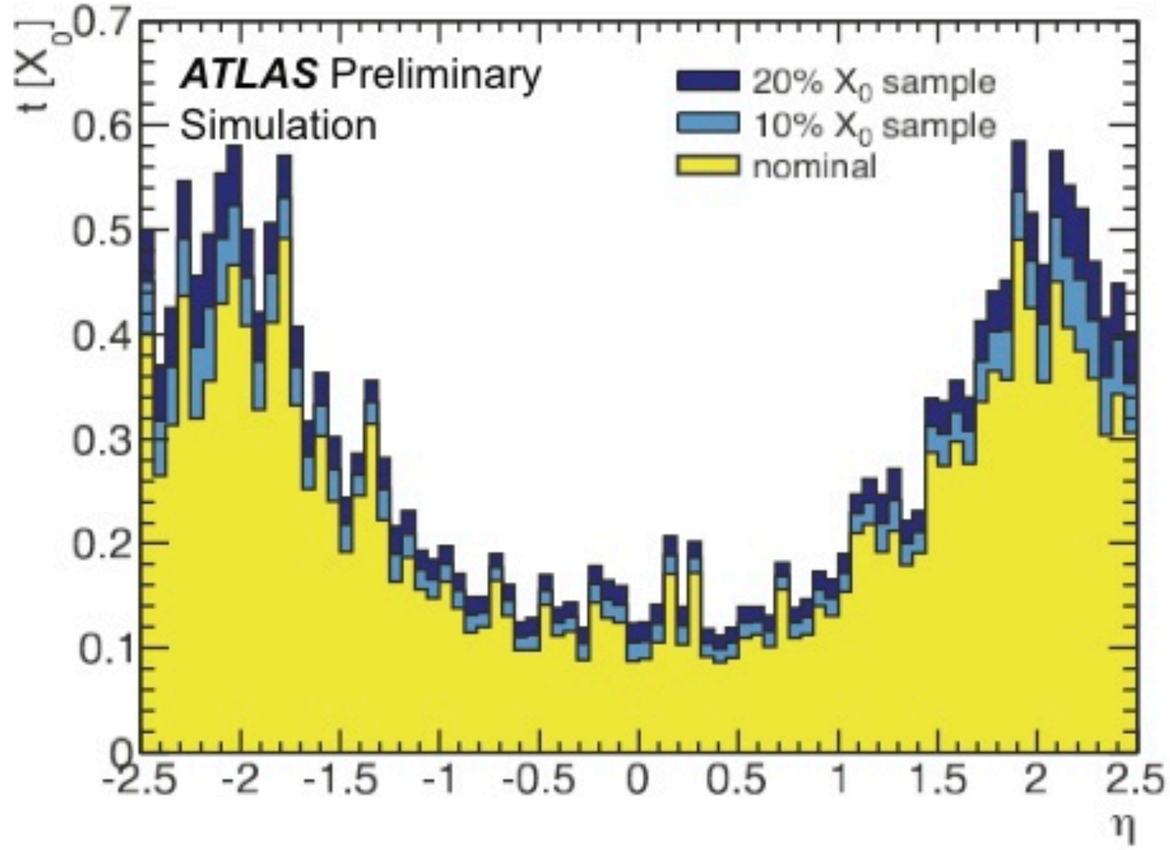
physics engine: Geant4

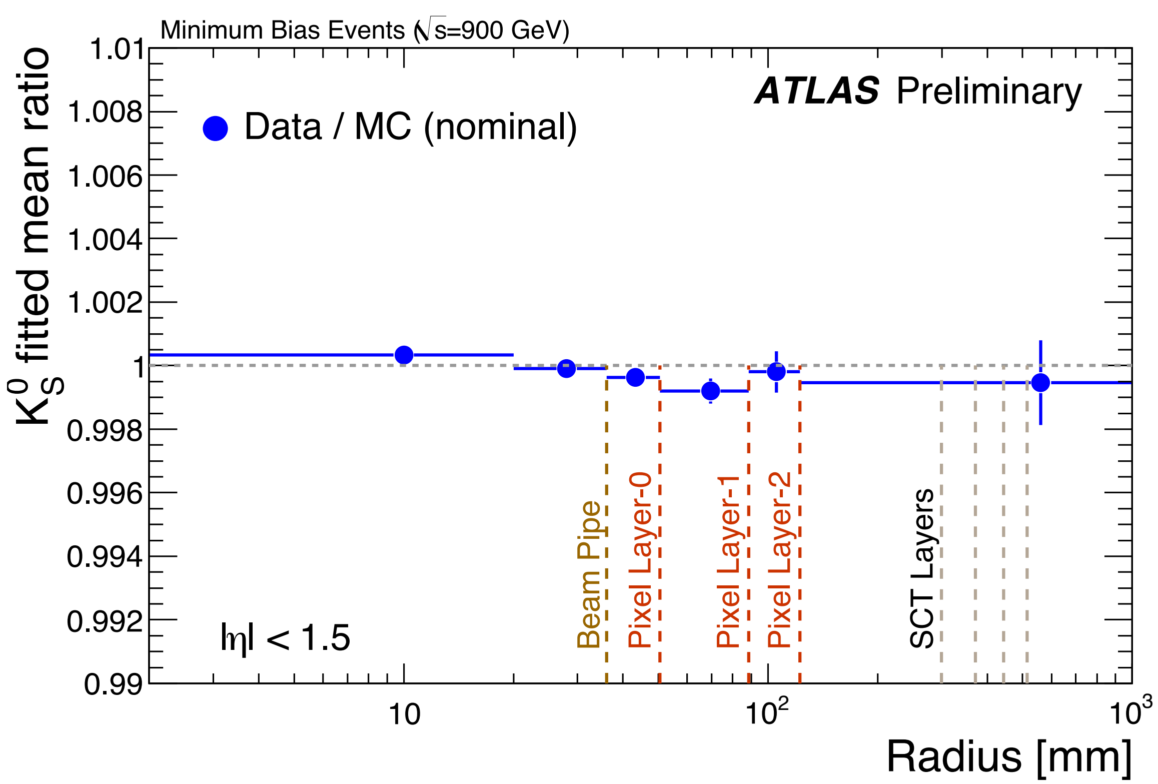
tuning possibilities: via geometry/material
physics list
step length
process cuts

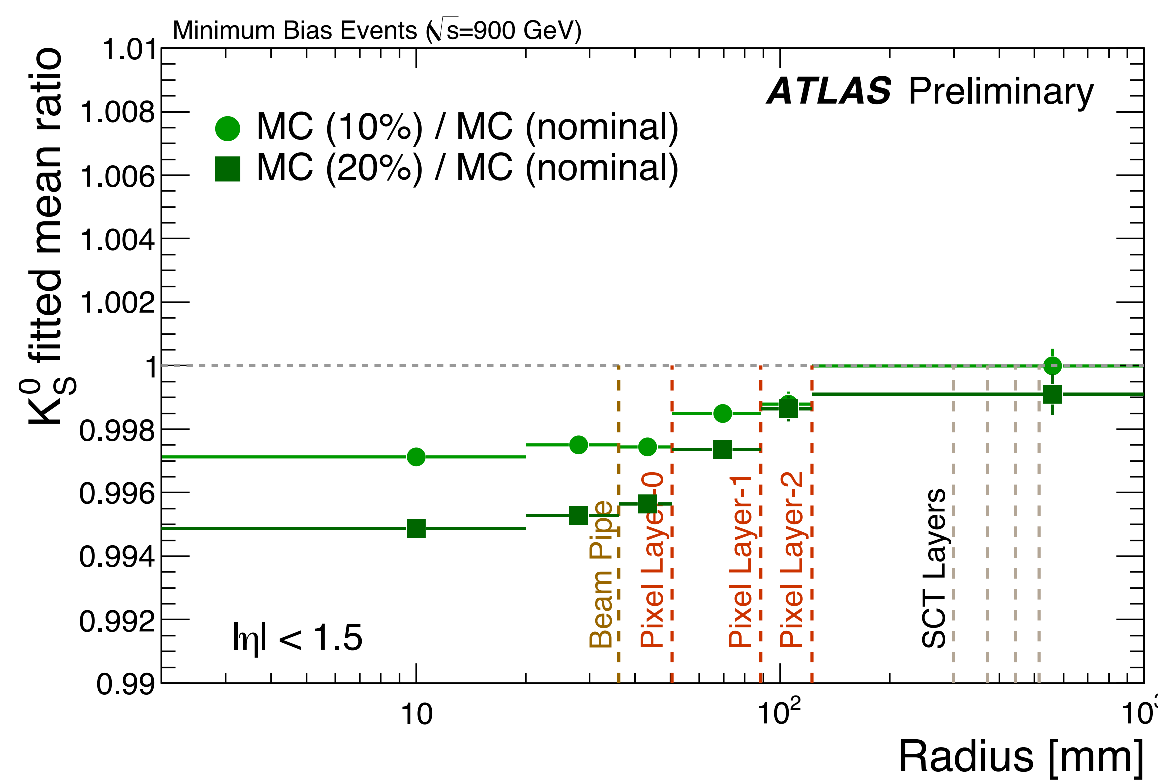
Geant4 ❖ tuning the simulation

adapting ID material (+ 10/20 %)
investigate effects on ID tracking

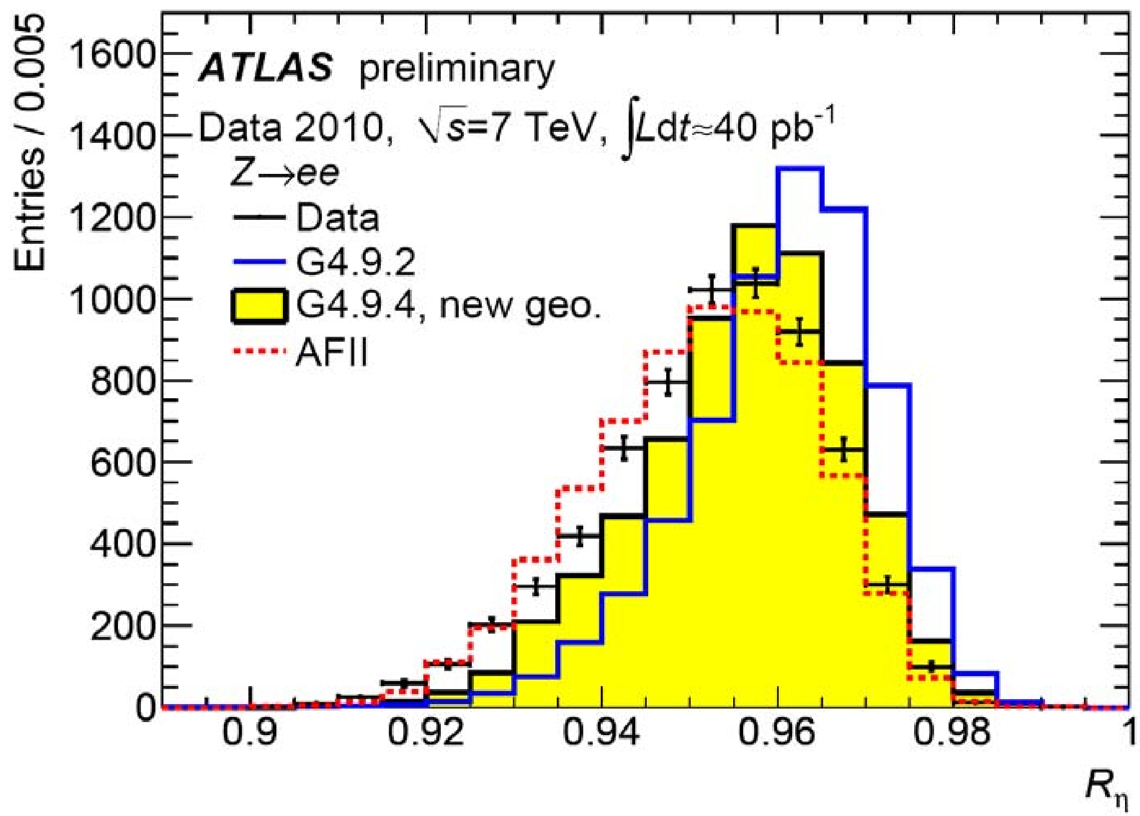
- to keep geometry structure
done by changing material
density of certain elements







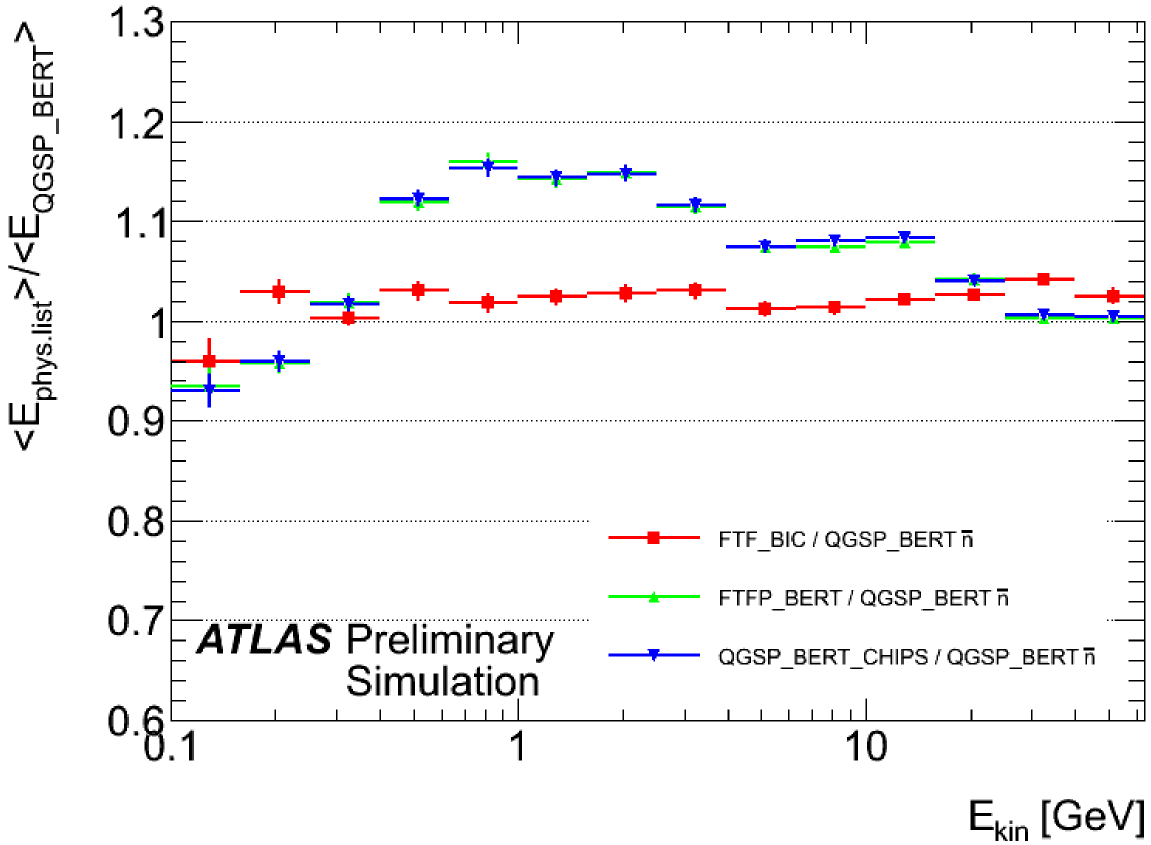
Geant4 ❖ tuning the simulation



changing the geometry description

see talk of Olivier Arnaez

electron shower shape dependence on geometry model, changing blended material into individual layers

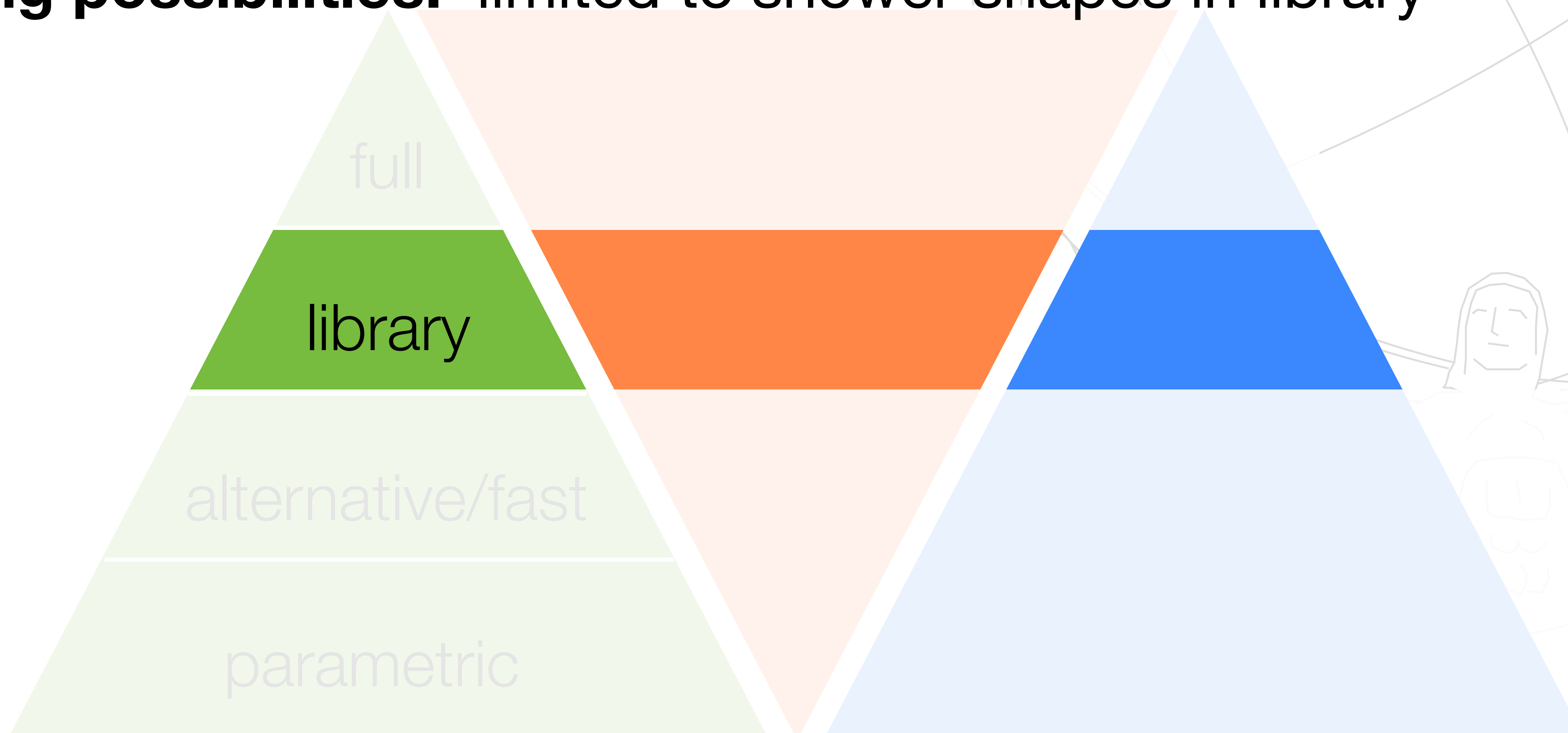


changing the physics list

ATLAS calorimeter response to anti-neutrons ($0.1 < p_T < 50$ GeV)

The library approach ❖ Frozen Showers

geometry model: Geant4 (translated from GeoModel)
physics engine: Geant4 (library, pre-simulated showers)
tuning possibilities: limited to shower shapes in library



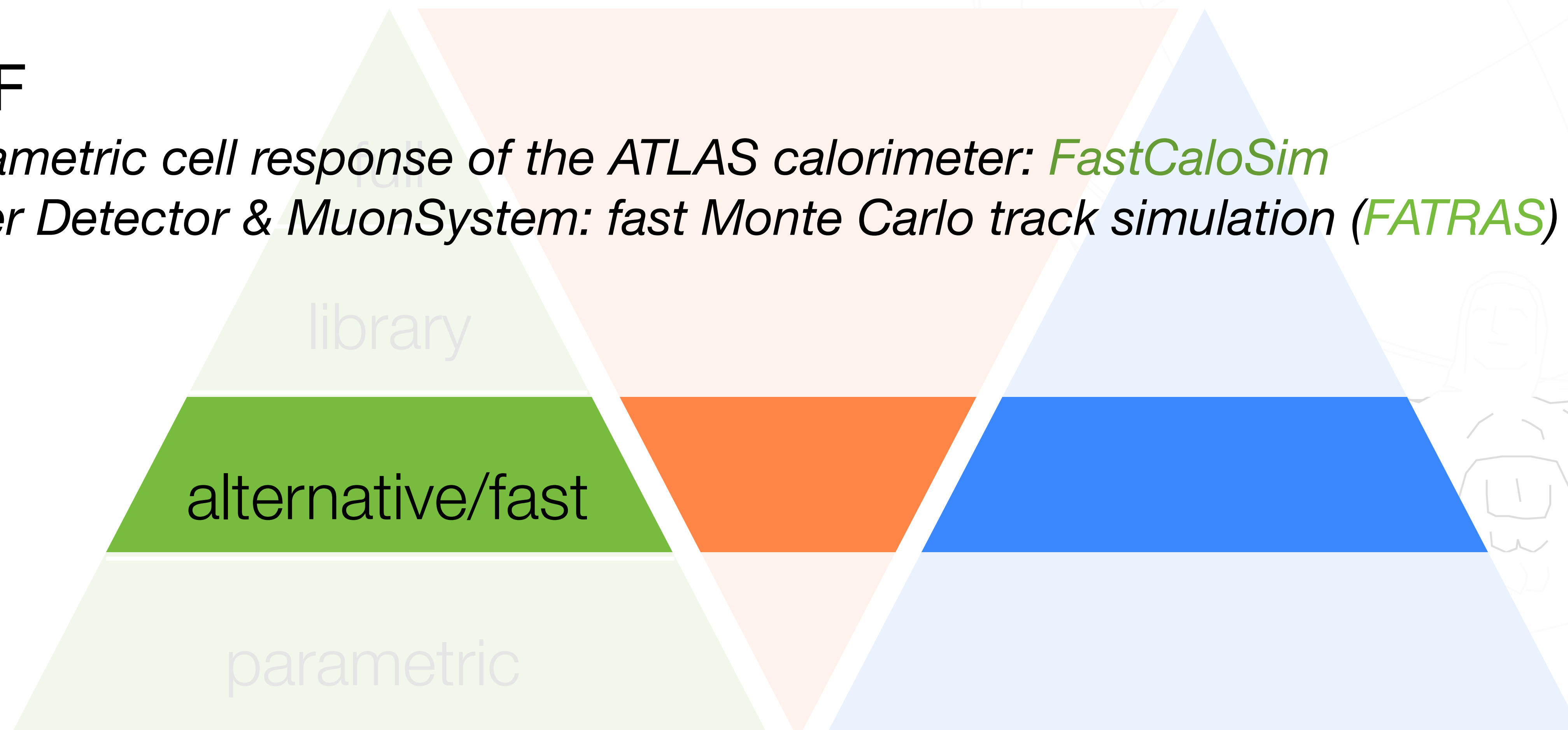
Fast simulation ❖ AFII & AFIIF

AFII

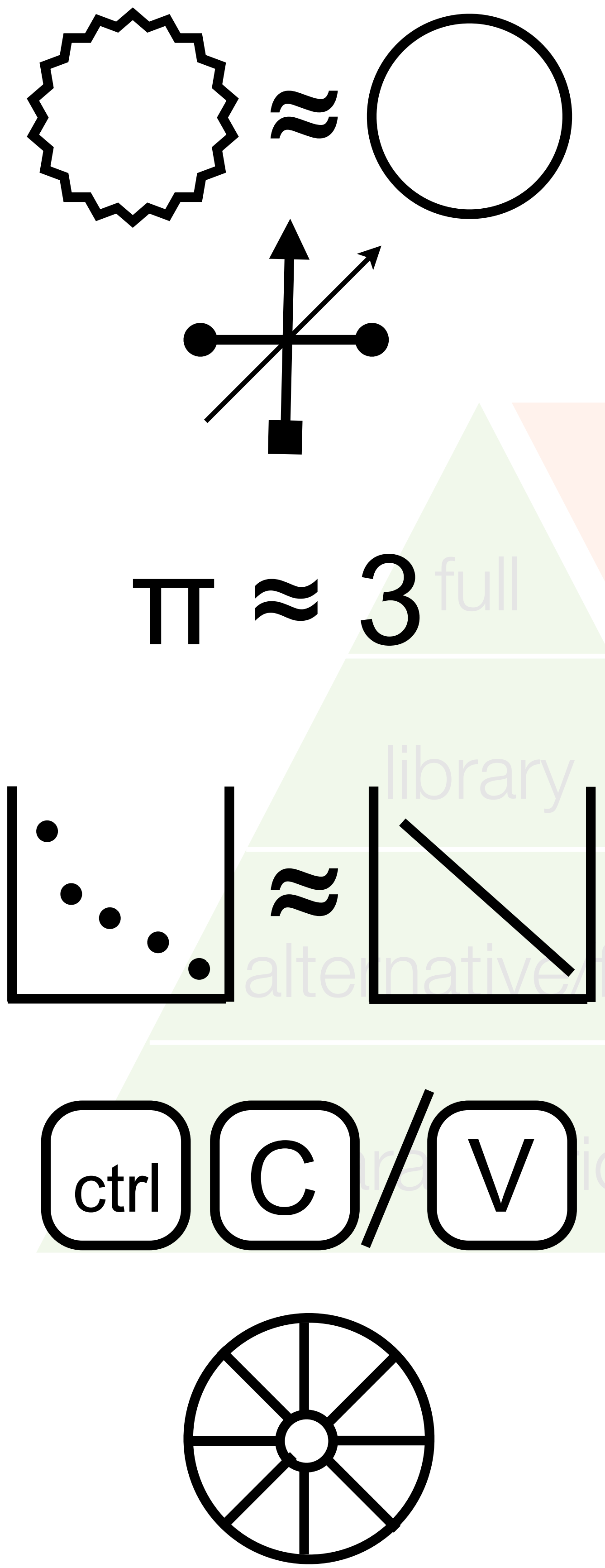
- *parametric cell response of the ATLAS calorimeter: FastCaloSim*
- *Inner Detector & Muon System: Geant4*

AFIIF

- *parametric cell response of the ATLAS calorimeter: FastCaloSim*
- *Inner Detector & MuonSystem: fast Monte Carlo track simulation (FATRAS)*



Fast simulation ❖ Ways to speed up simulation



approximate geometry

optimise transport and navigation

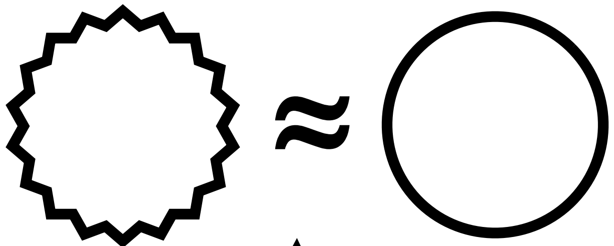
approximate models

parameterisations

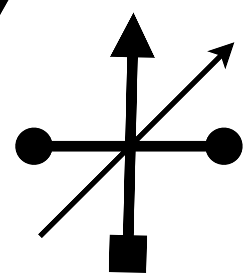
take shortcuts

use new technologies

Fast simulation ❖ Ways to speed up simulation



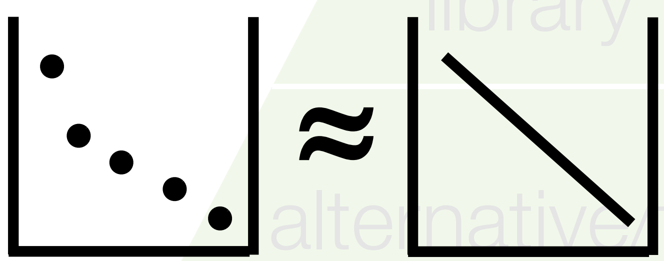
approximate geometry



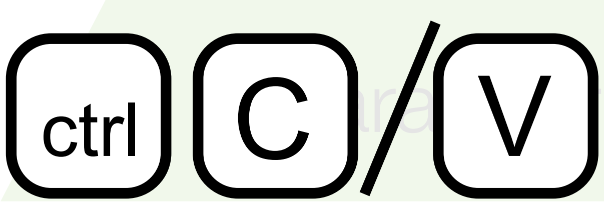
optimise transport and navigation

π ≈ 3

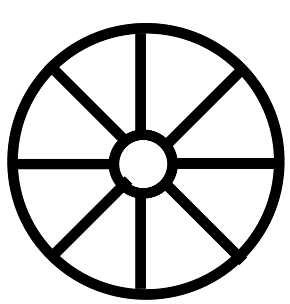
approximate models



parameterisations



take shortcuts



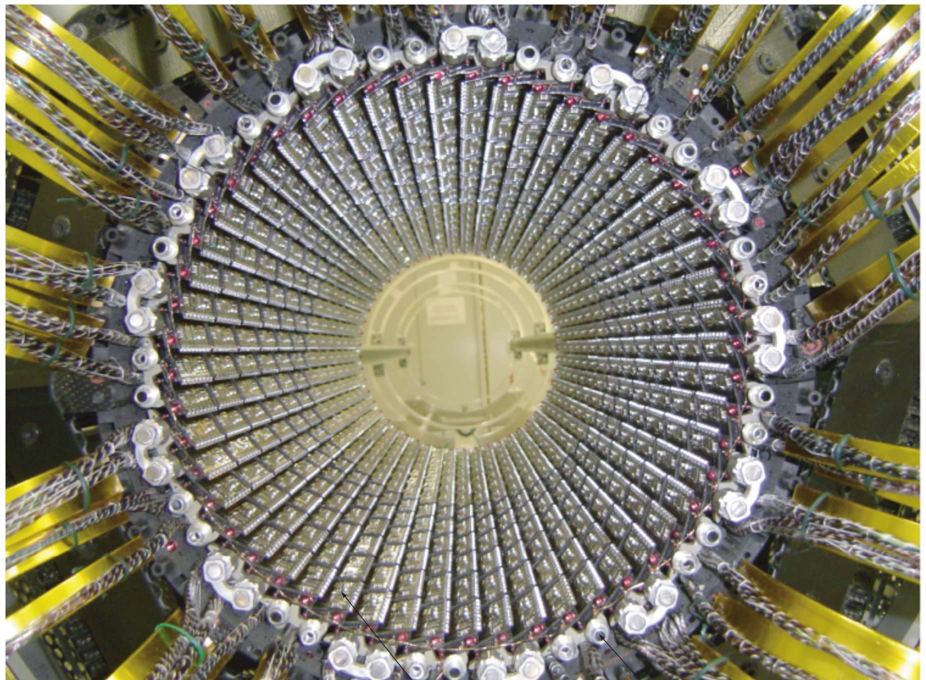
use new technologies

... danger of re-invent the wheel

Fast simulation ❖ simplified geometry model ≈

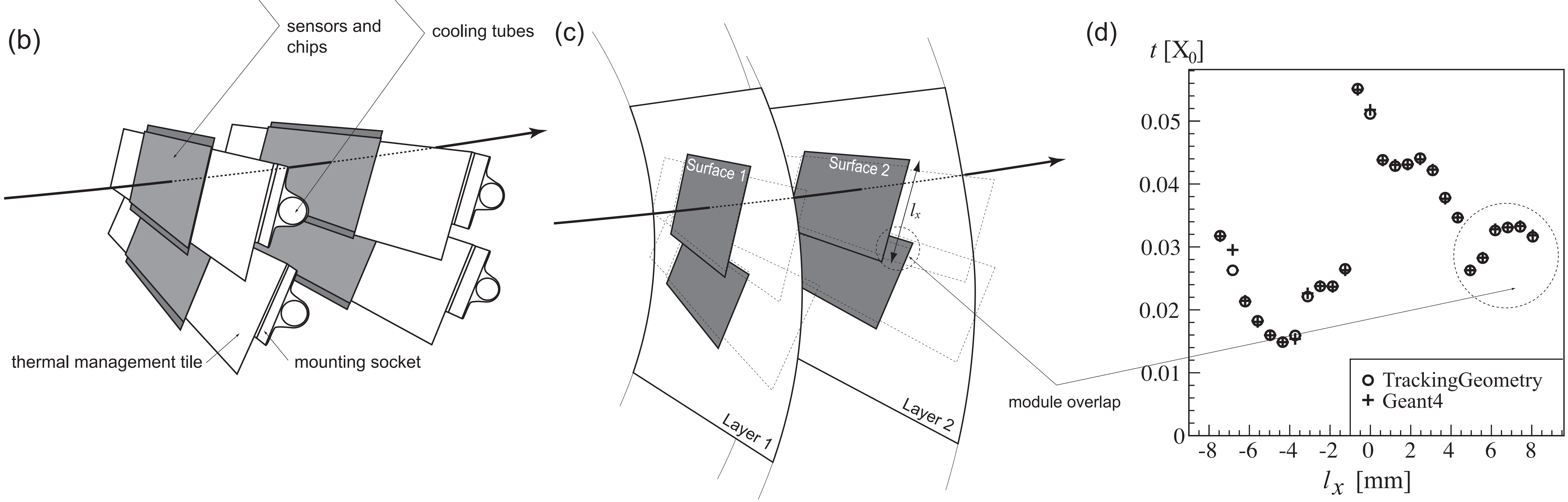
ATLAS TrackingGeometry

- *Inner Detector & Calorimeter:* *simplification to layers and cylindrical volumes keeping the exact description of sensitive elements*



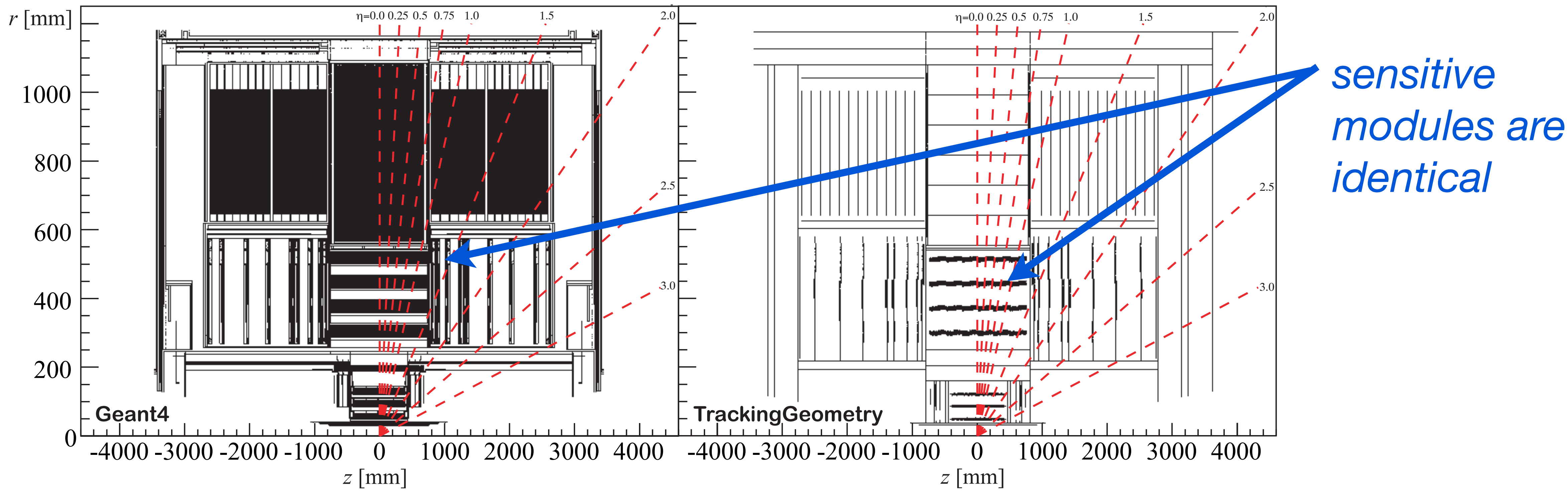
navigation through the geometry is only done using the layers and volume boundaries, modules are found by intersection with layer

material is mapped onto layers using Geant4 description and geantinos

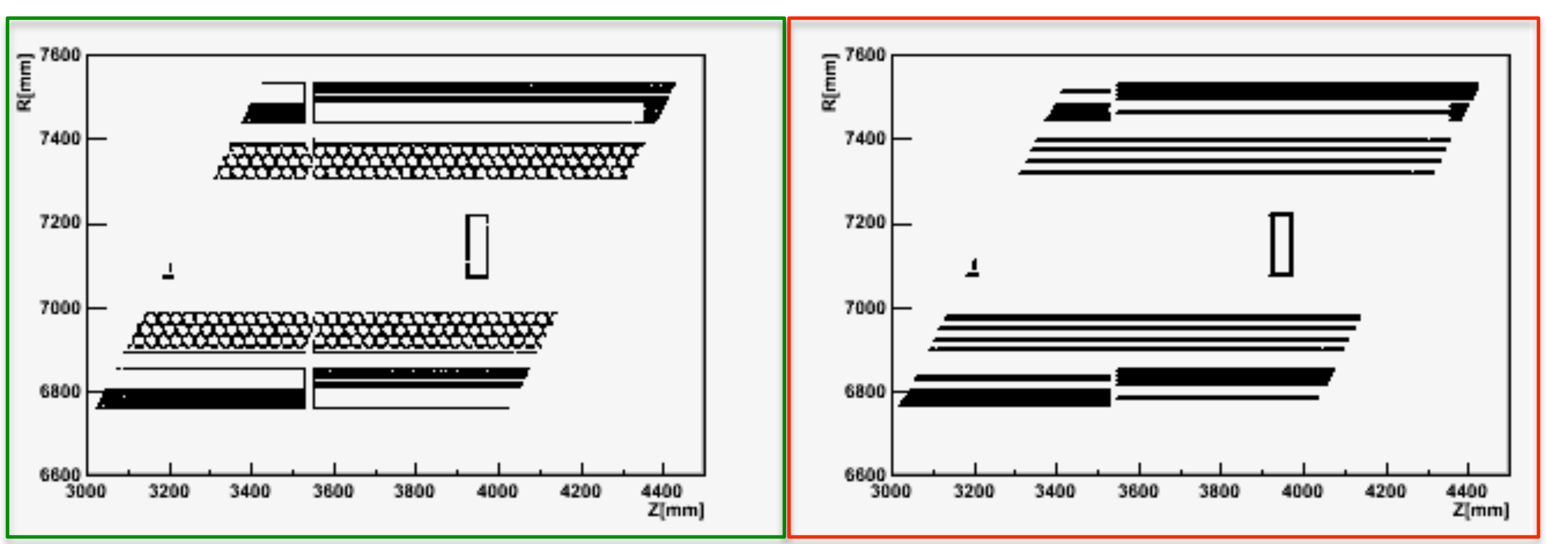


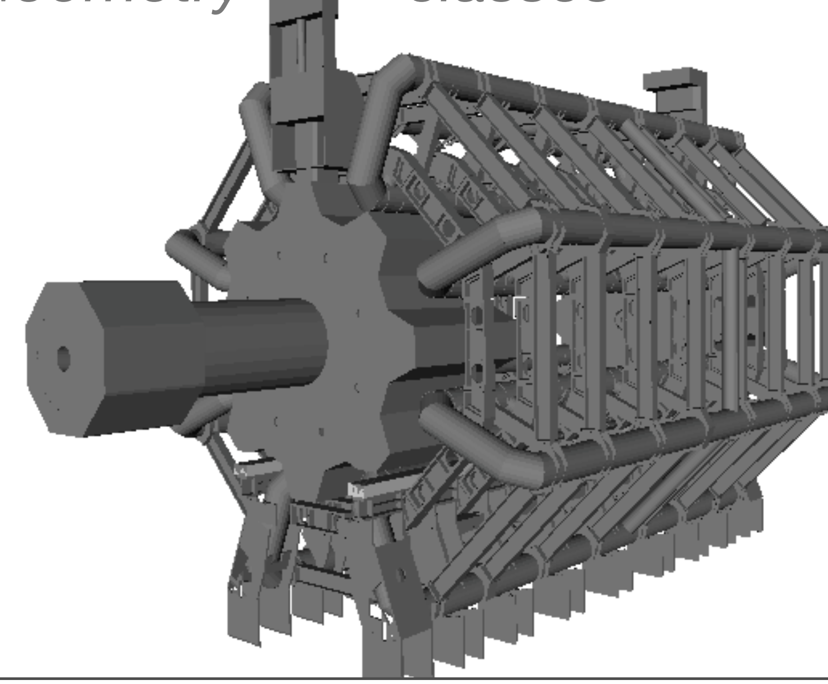
Fast simulation ❖ simplified geometry model ≈

- *Example Inner Detector:*
  O(100) layers and detector boundaries



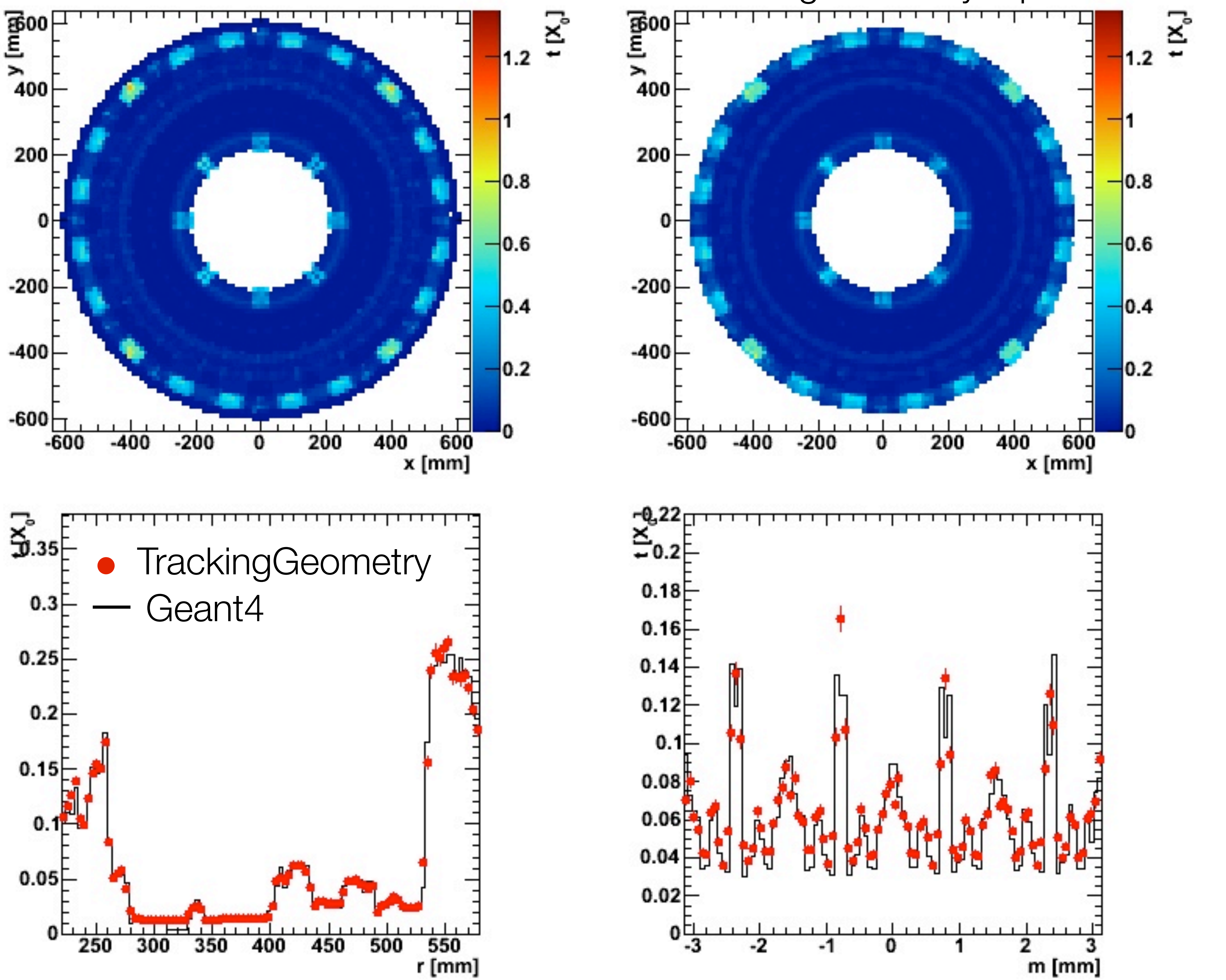
- *Muon System:*
  simplification of chambers & exact transcript into TrackingGeometry classes





Geant4 / TrackingGeometry material comparison

Geant4 material | TrackingGeometry representation



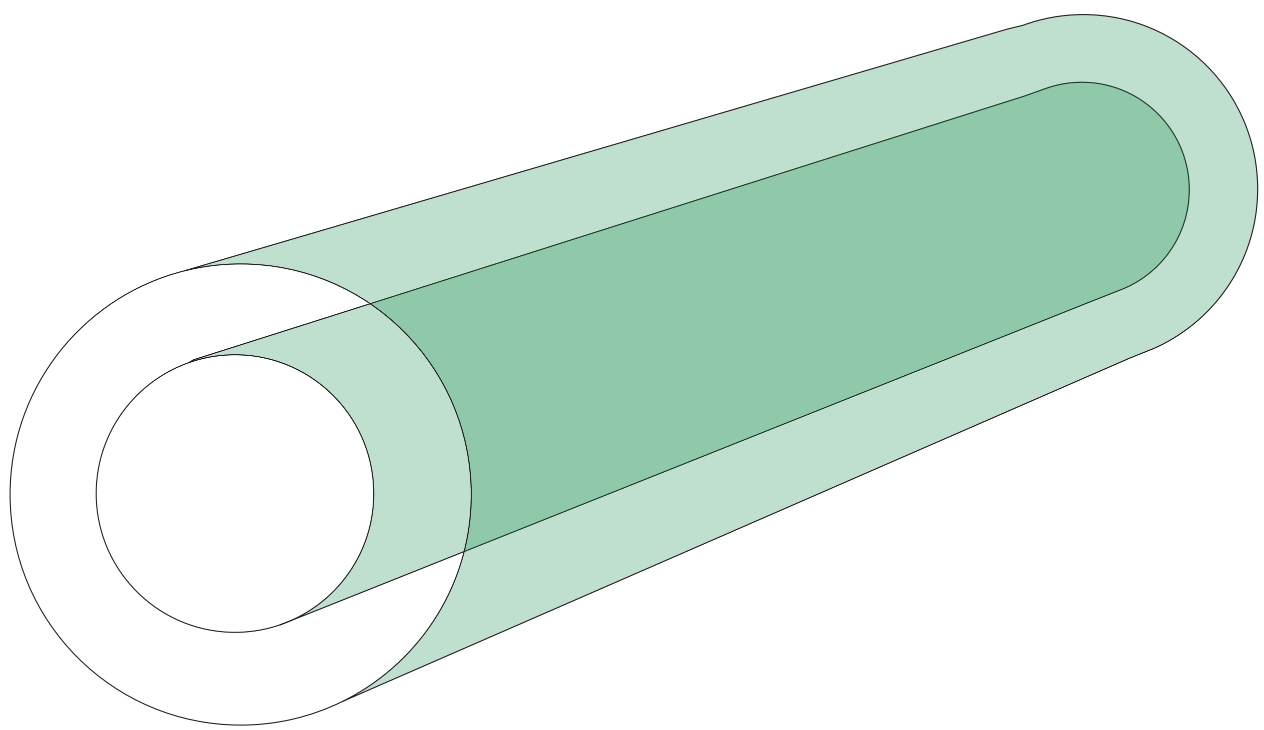
example for TrackingGeometry layer

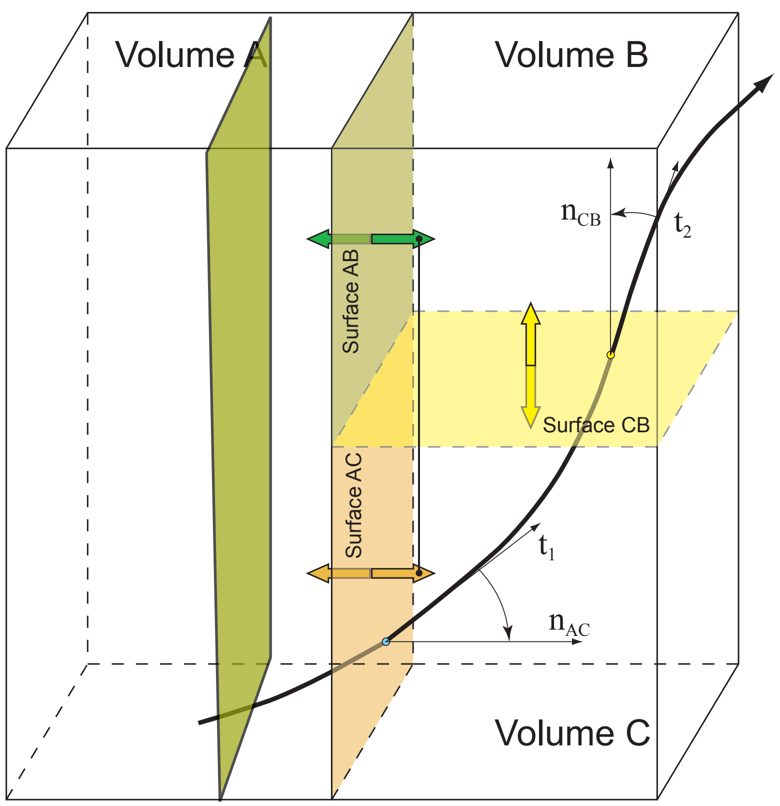
Fast simulation ❖ optimised transport model

ATLAS TrackingGeometry is a fully connective geometry with interlinked nodes

- built from one common surface class to be used with extrapolation engine

- result of propagation to current node guides to next node





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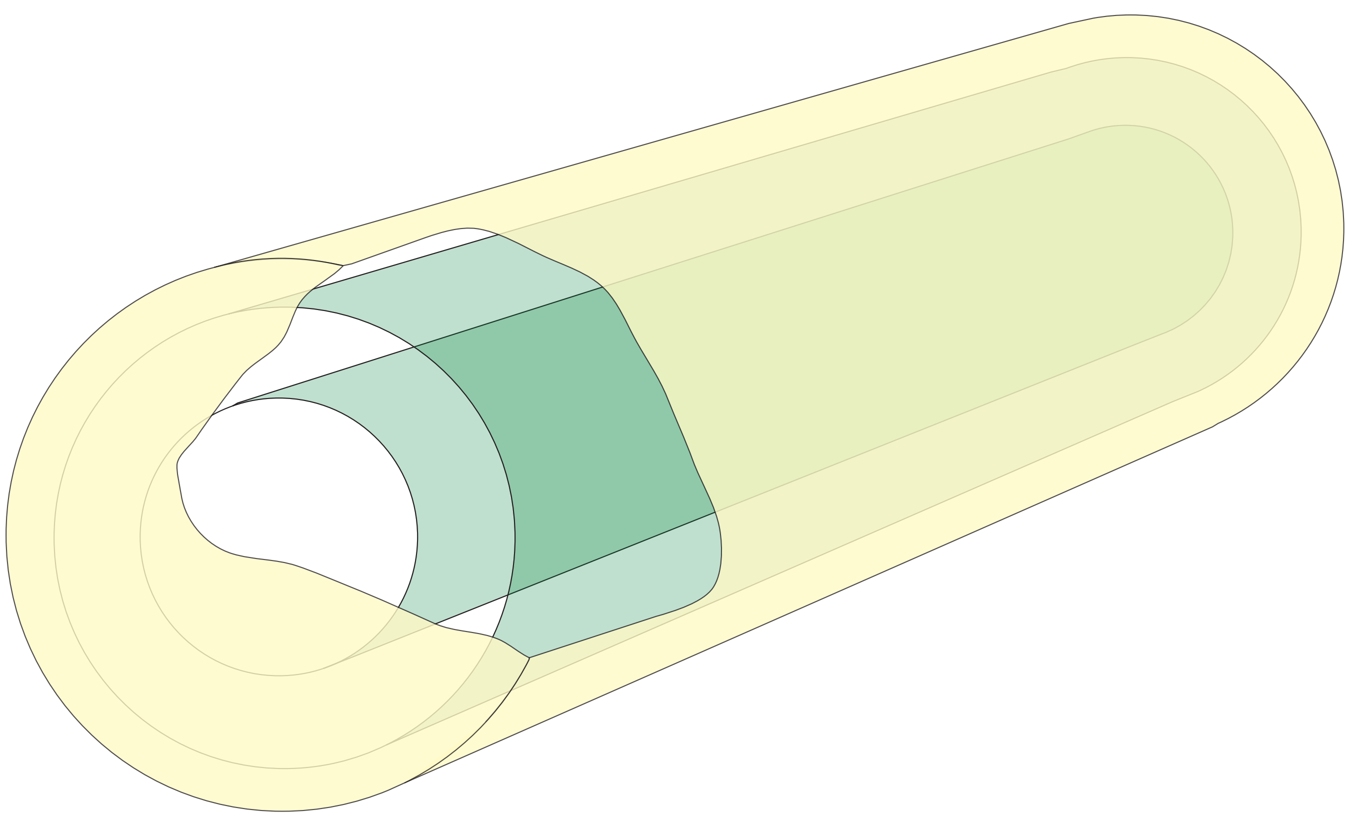

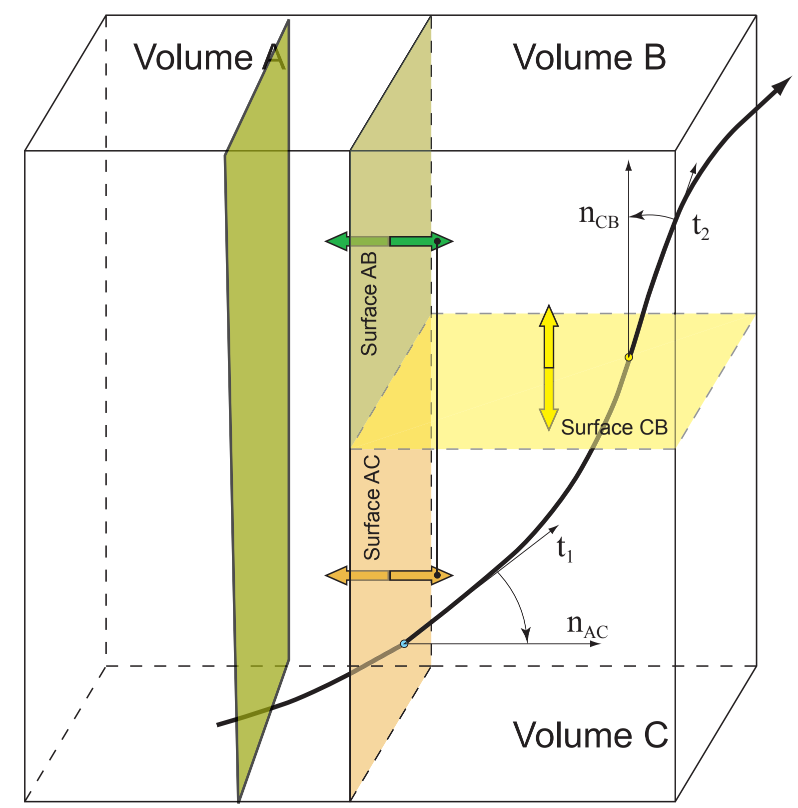

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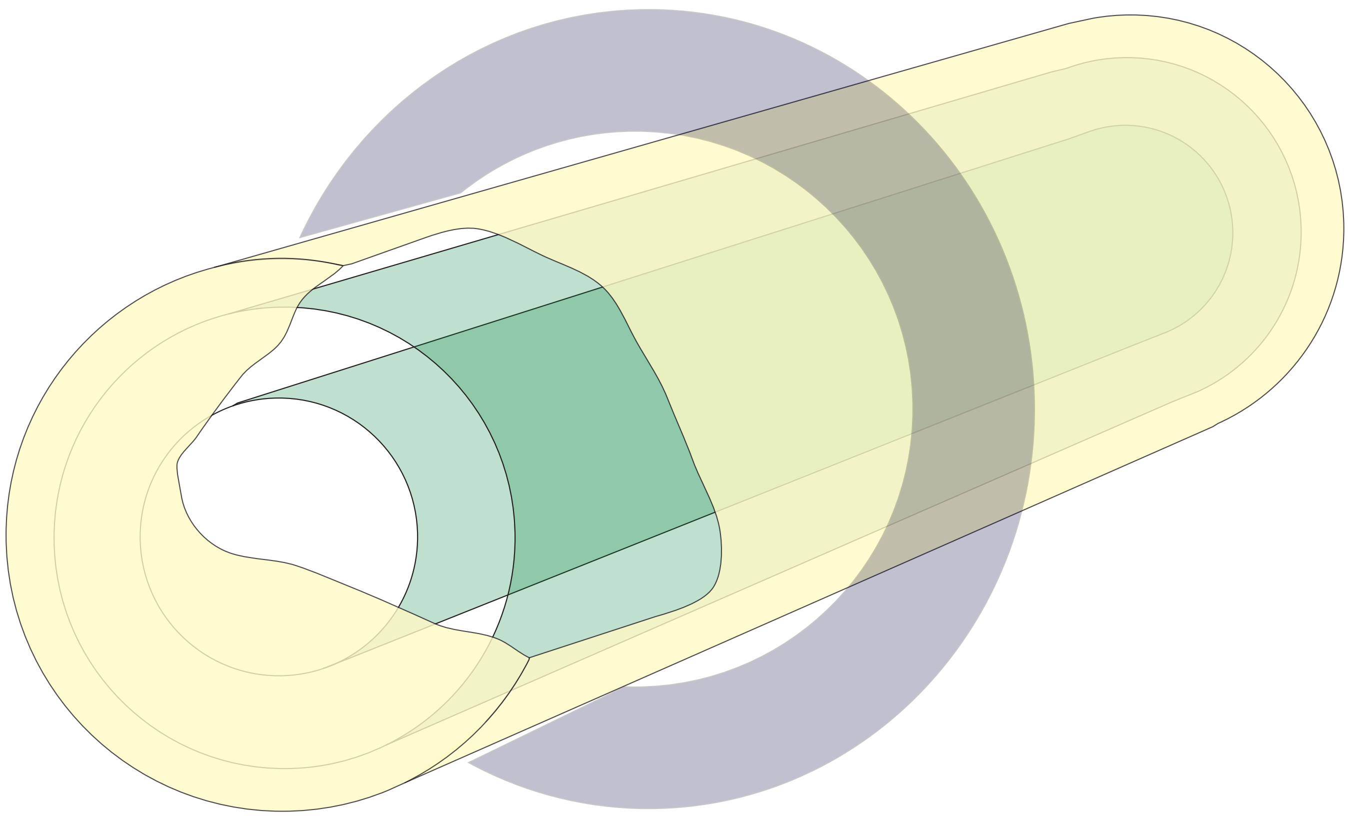

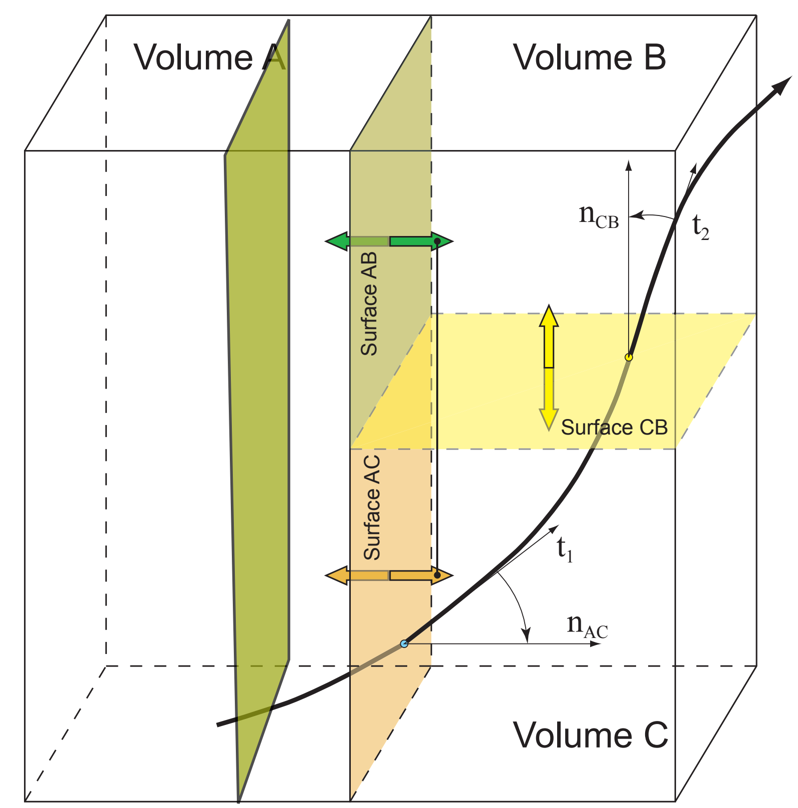

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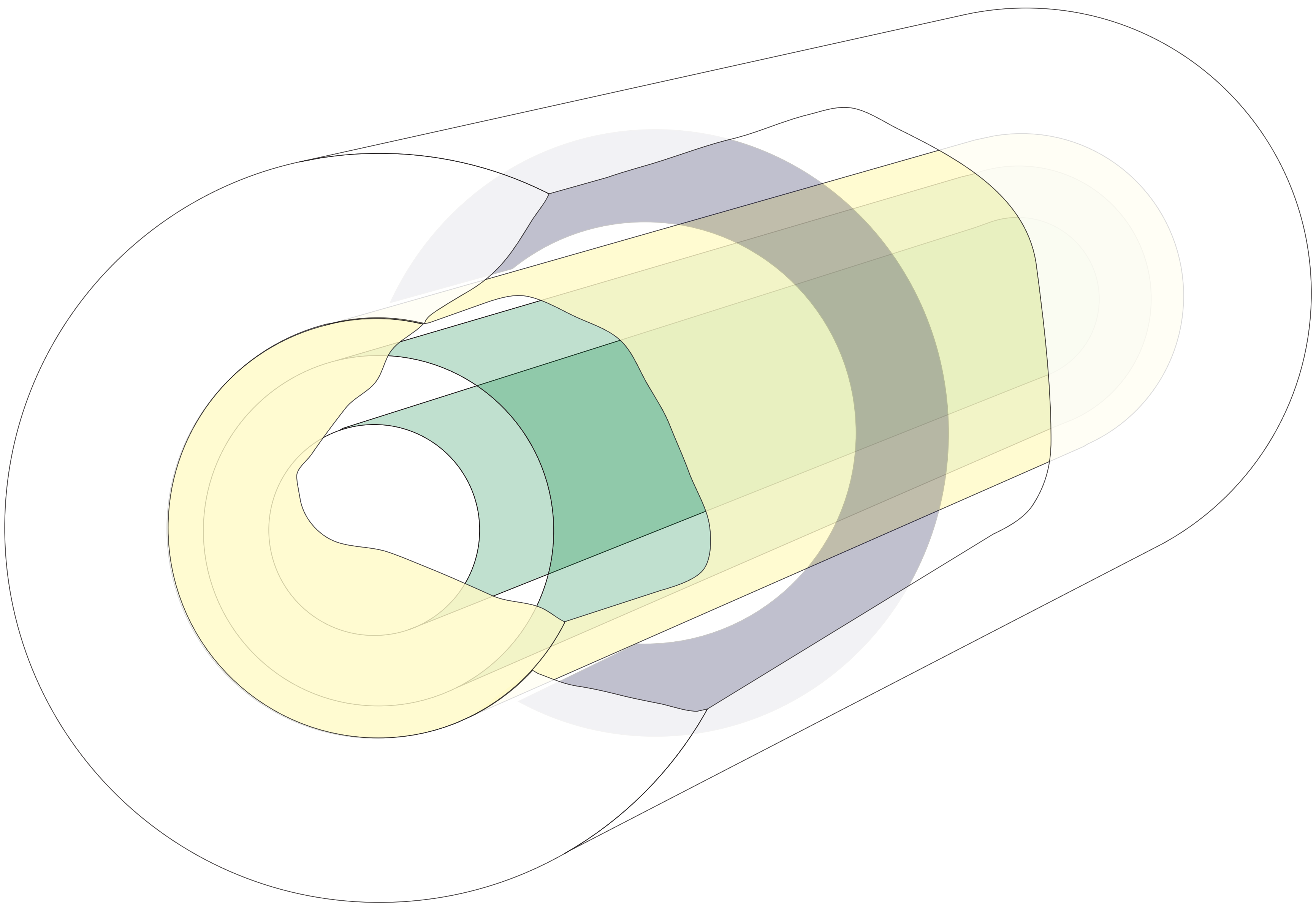

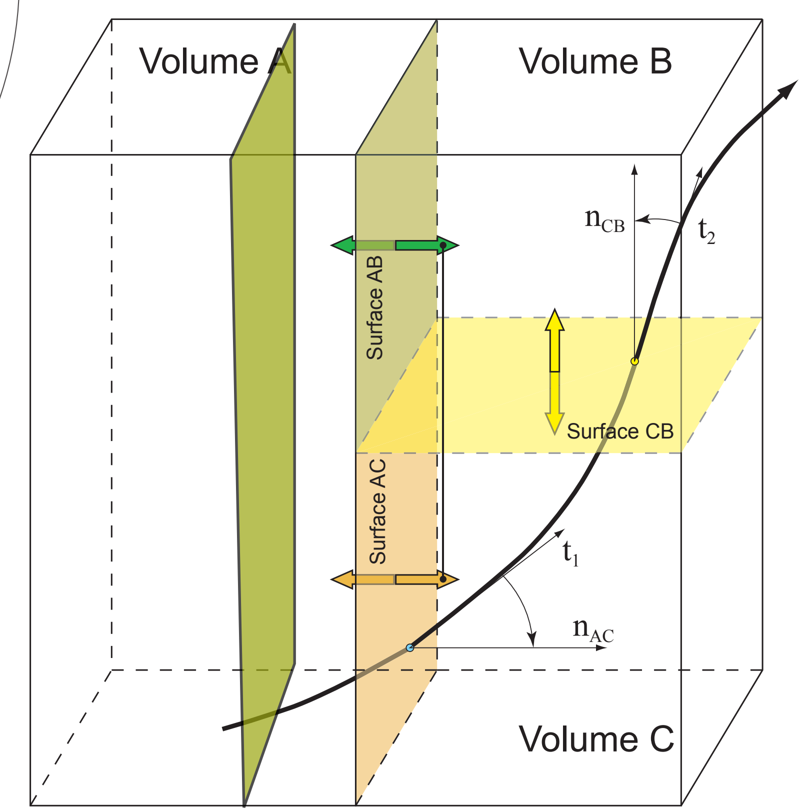

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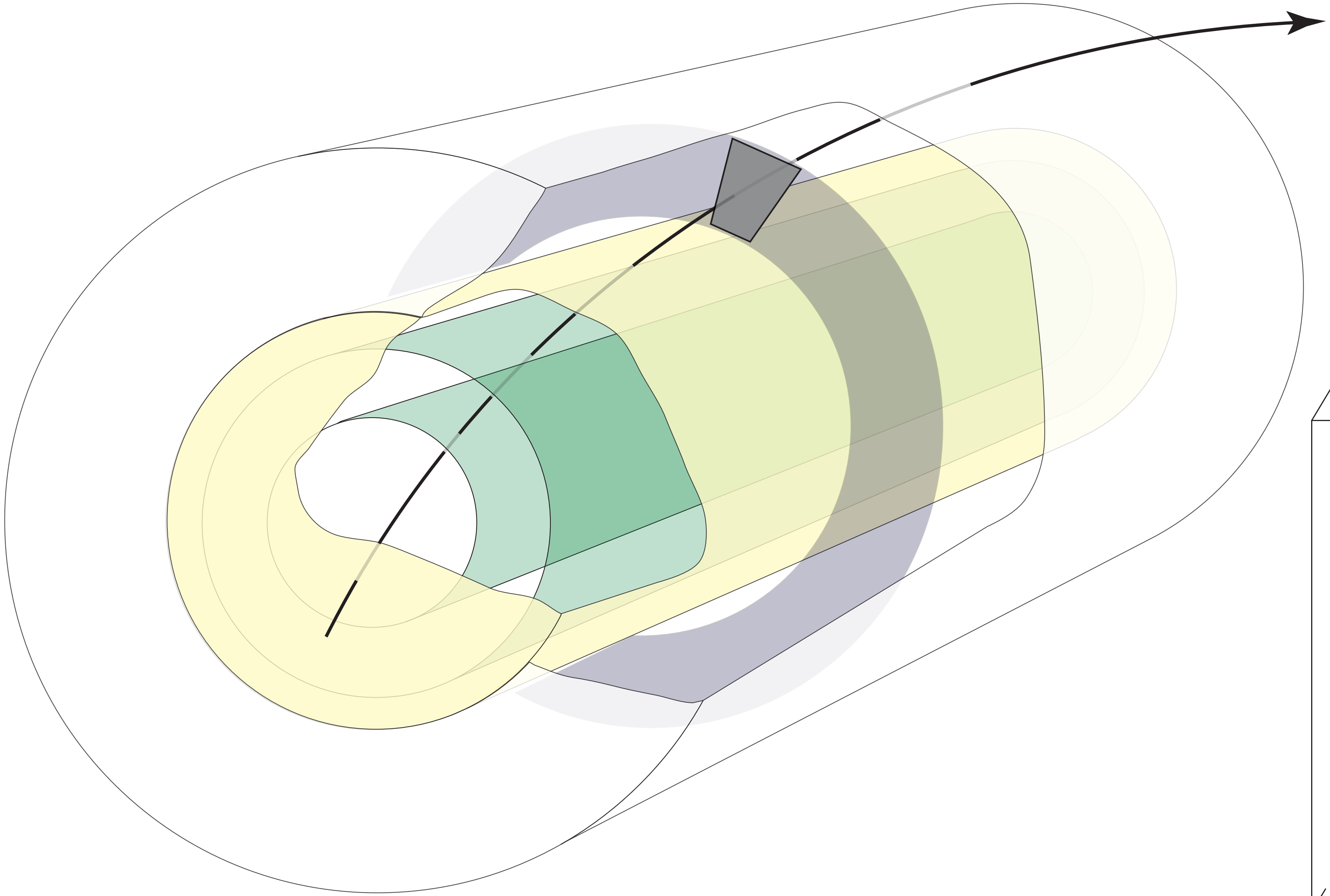

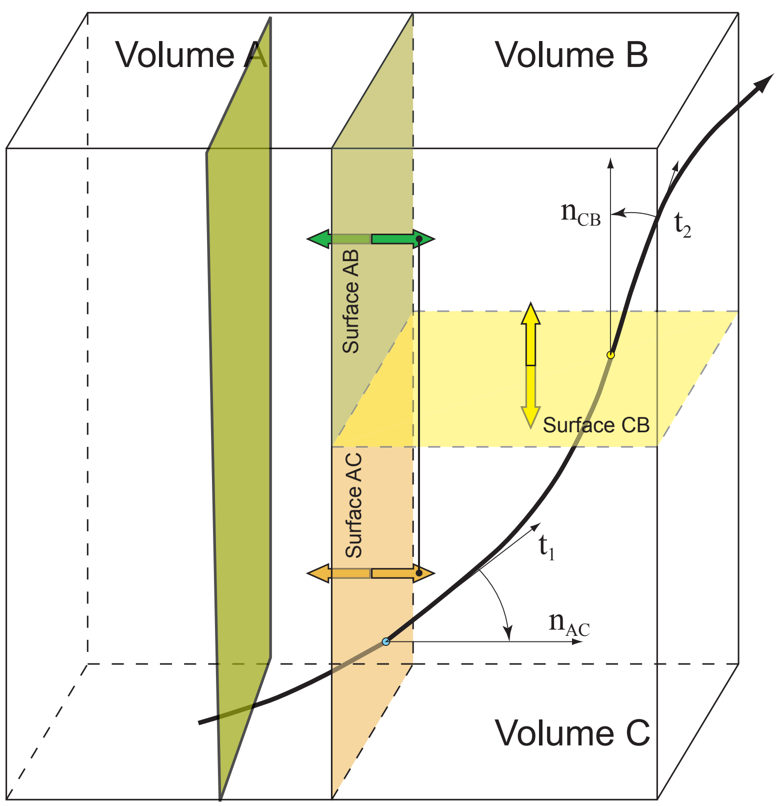

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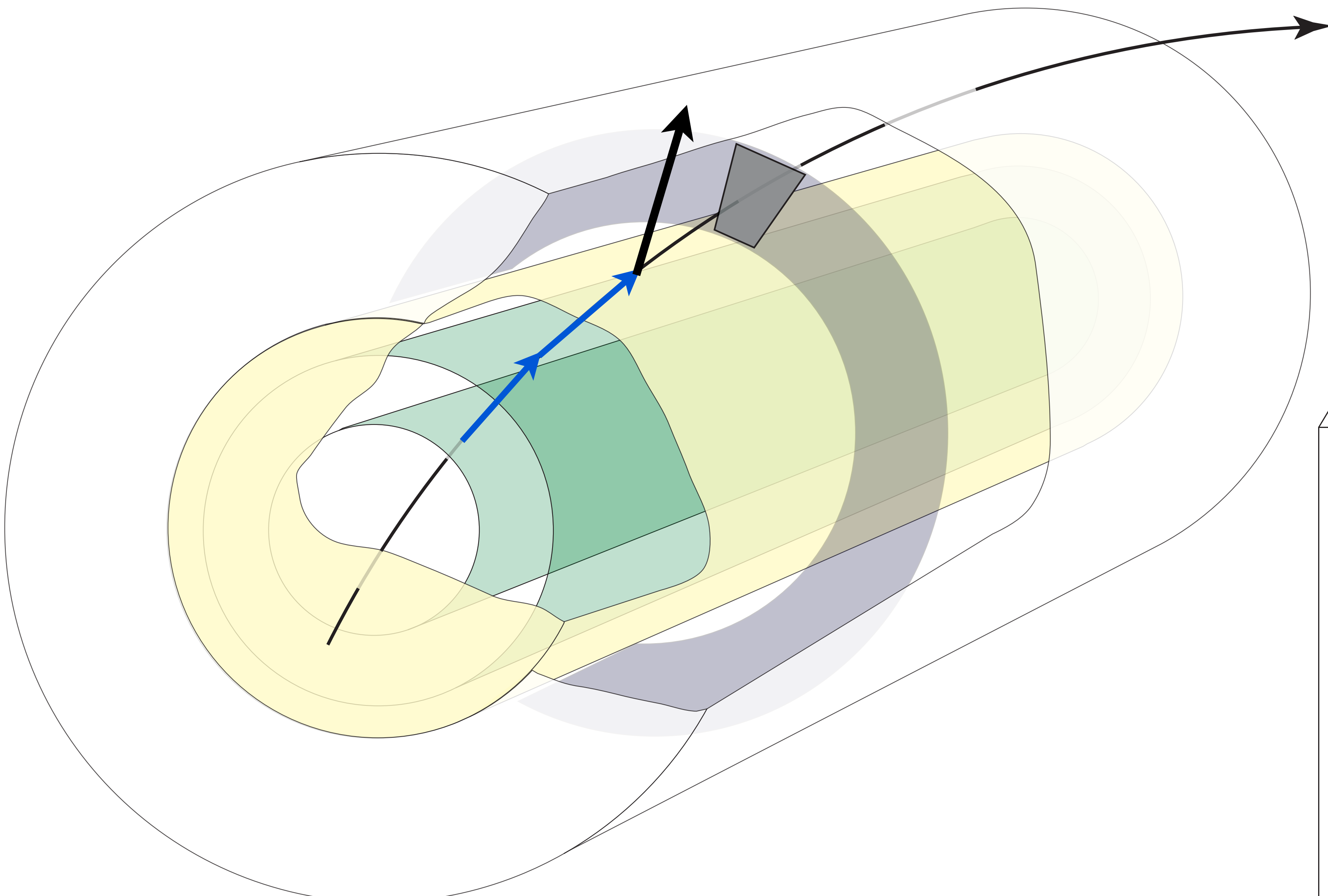
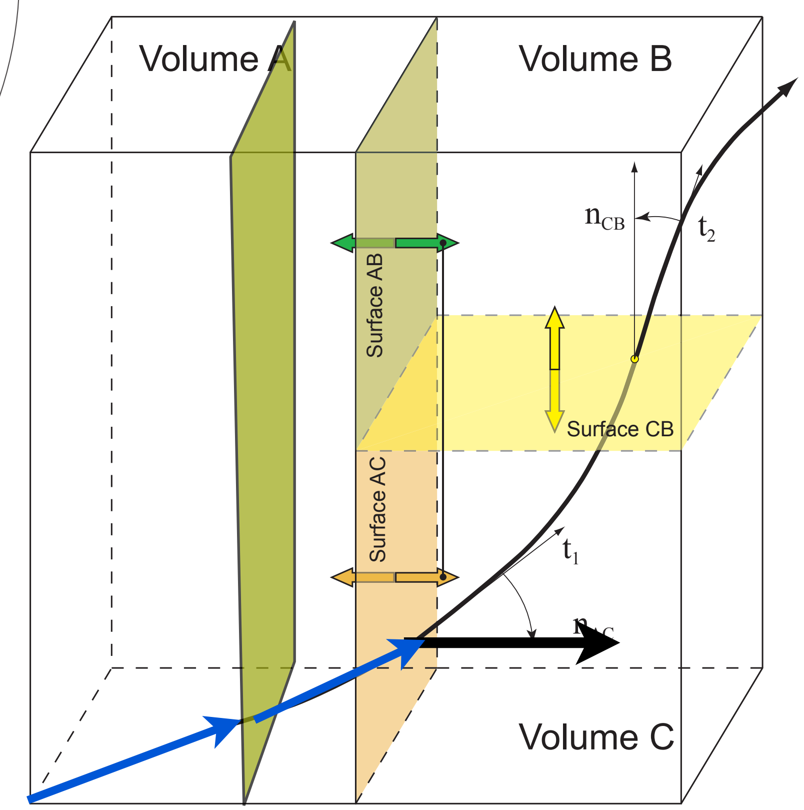
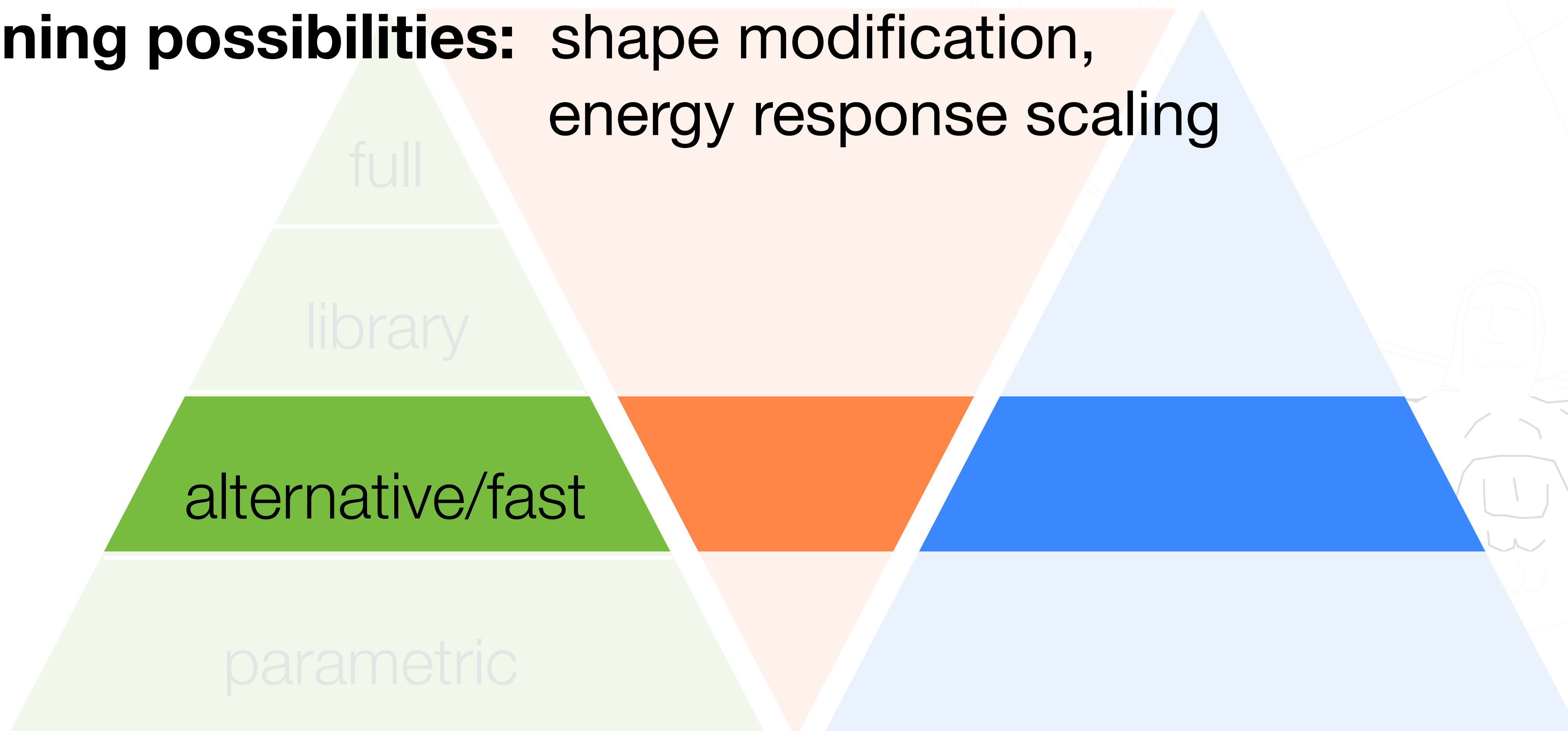
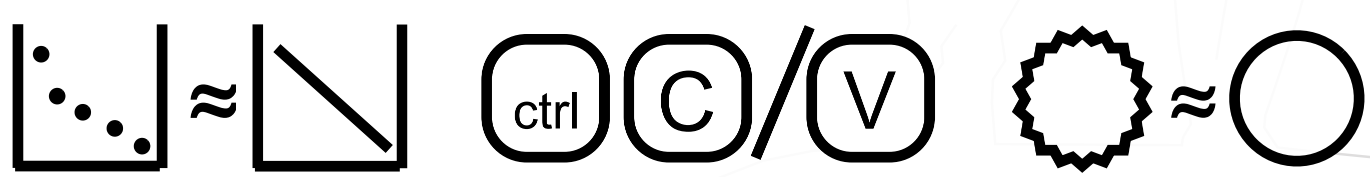




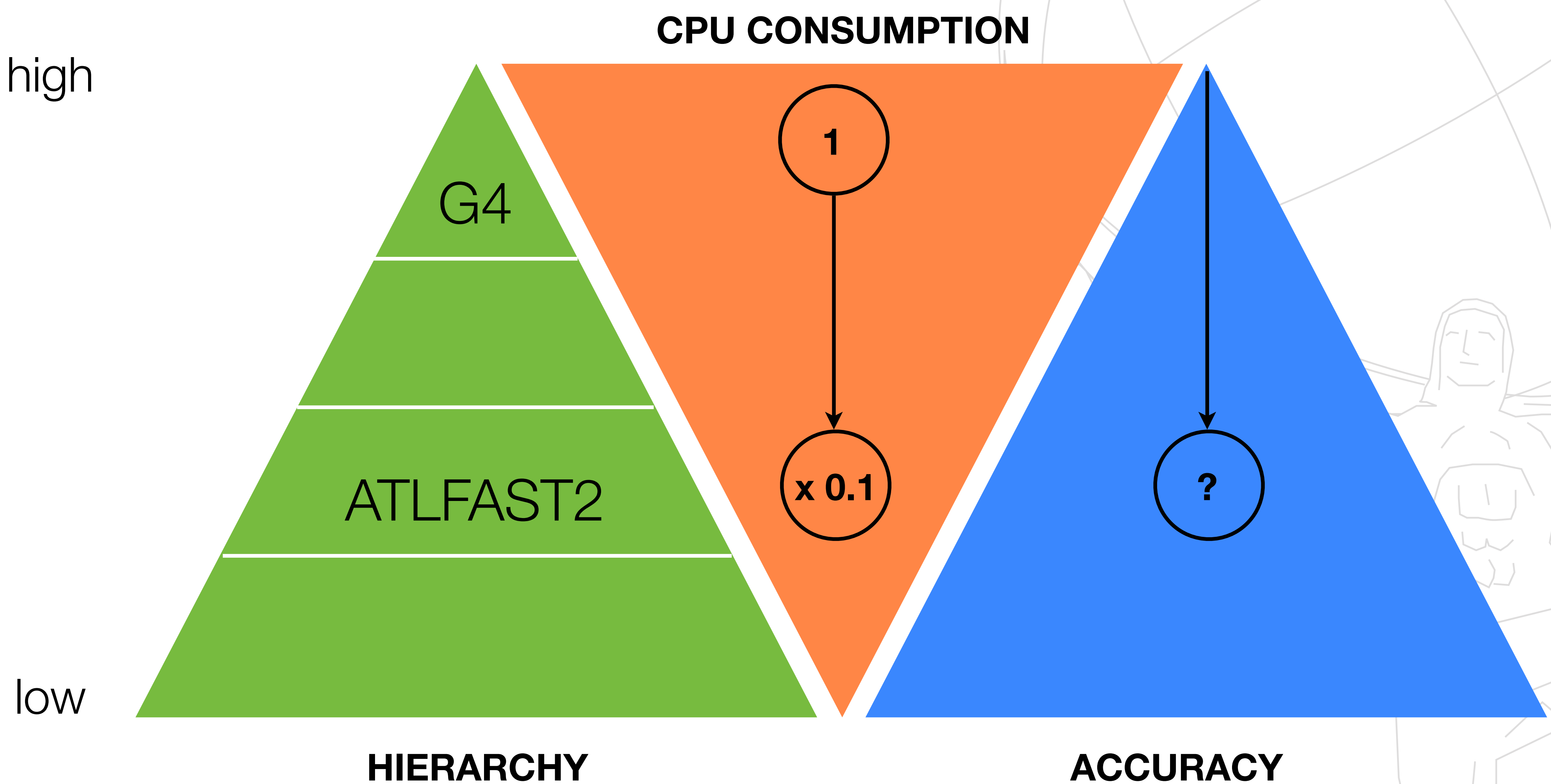
Fast simulation ❖ AFII (FastCaloSim)

geometry model: ATLAS calorimeter reconstruction geometry
physics engine: ATLAS extrapolation engine (transport)
shower shape parameterisation
tuning possibilities: shape modification,
energy response scaling





Fast simulation ❖ AFII



Fast simulation ❖ AFII

- *AFII setup:*

  Step 1:

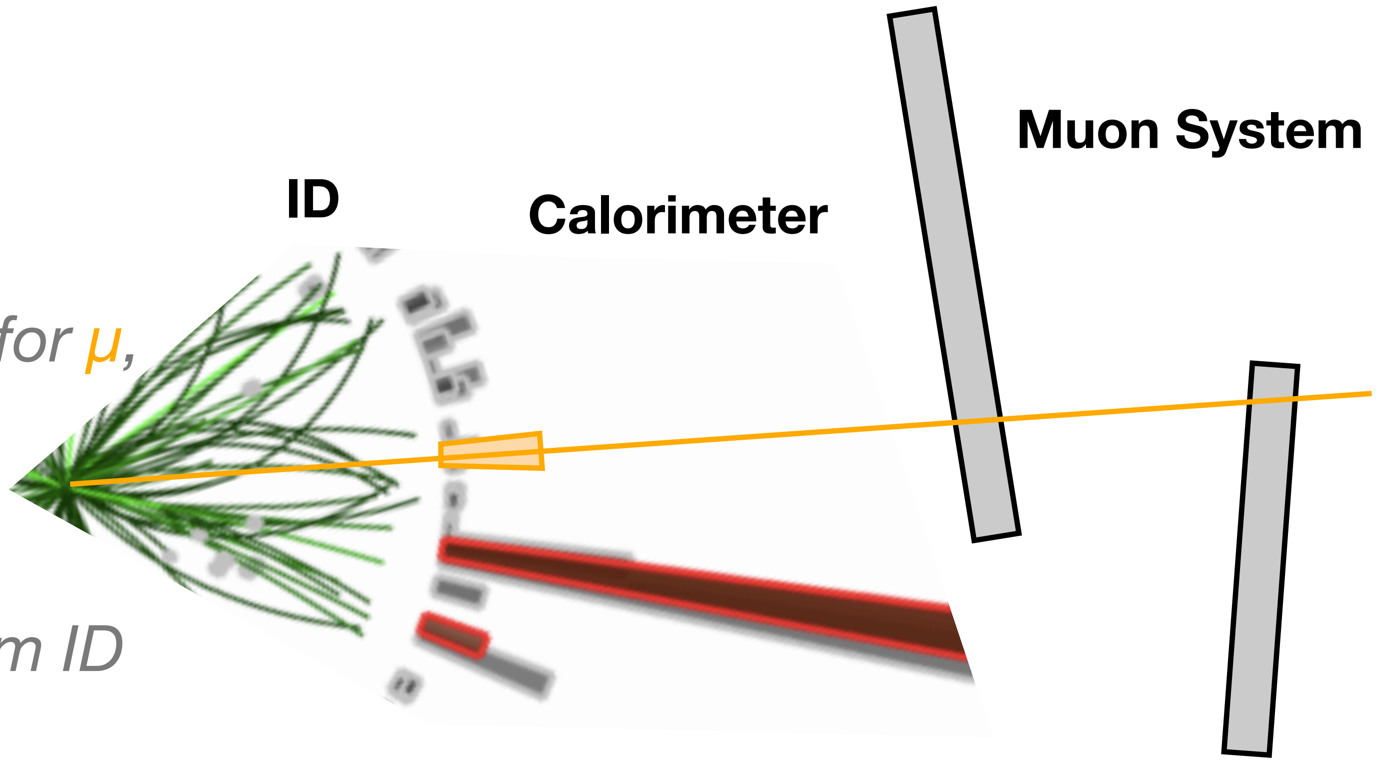
  Inner Detector with Geant4

  Calorimeter, Muon System with Geant4 for μ,

  all other particles are killed at Calo entry

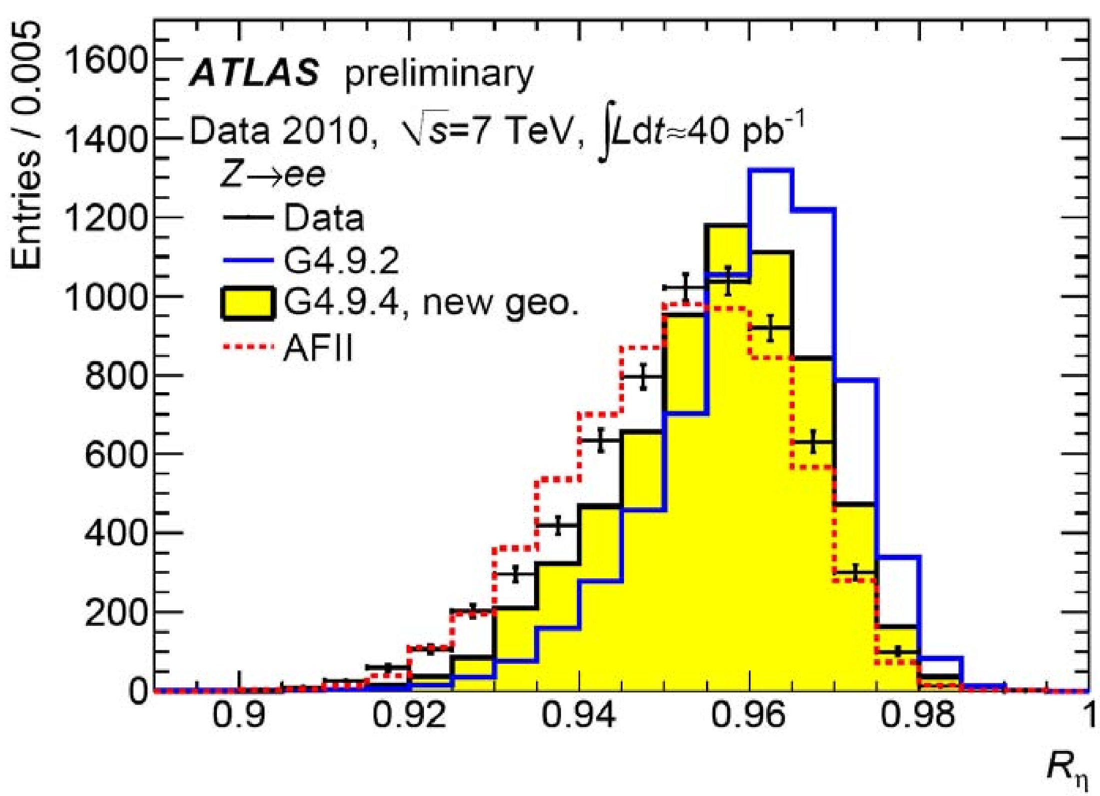
  Step 2:

  Calorimeter cell response from parameterisation applied to particles from ID

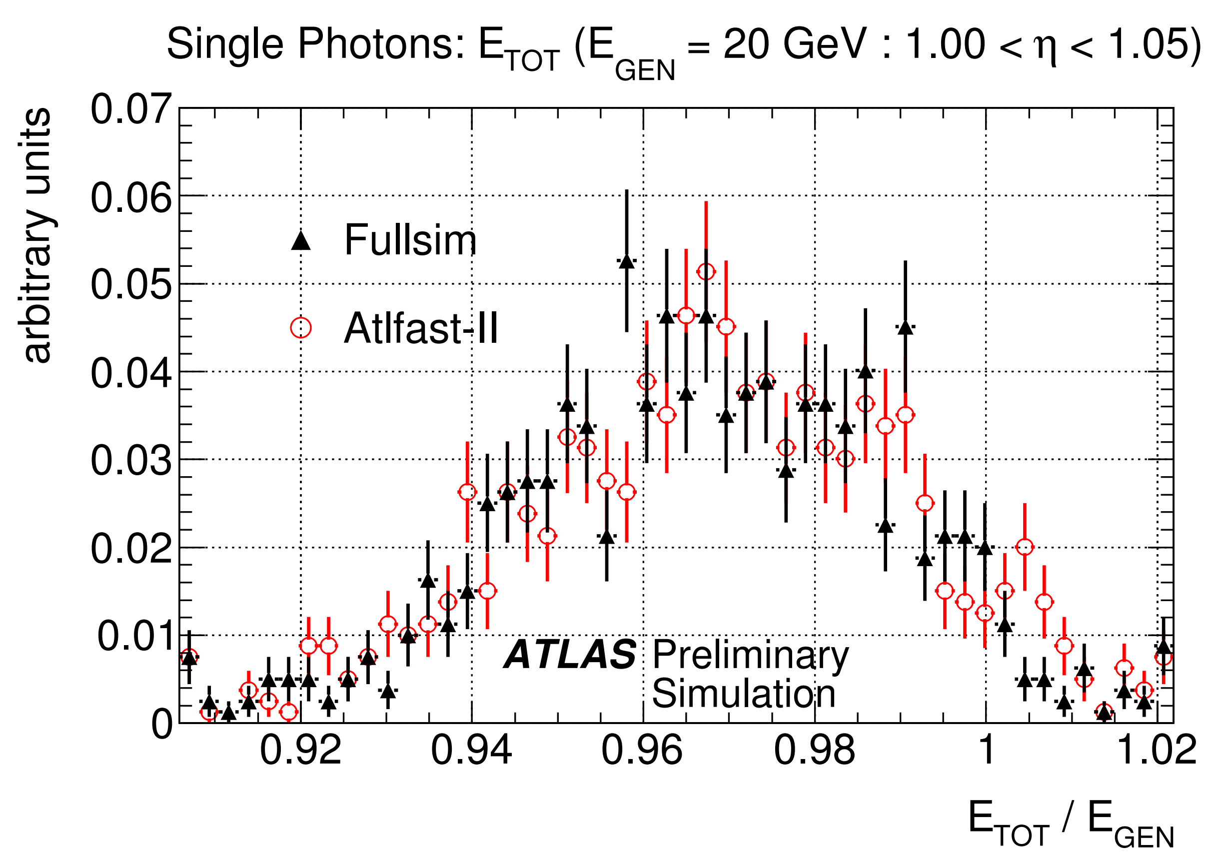


- *Shower parameterisation:*

  parameterisation of shower shape variables, allows tuning to data distributions

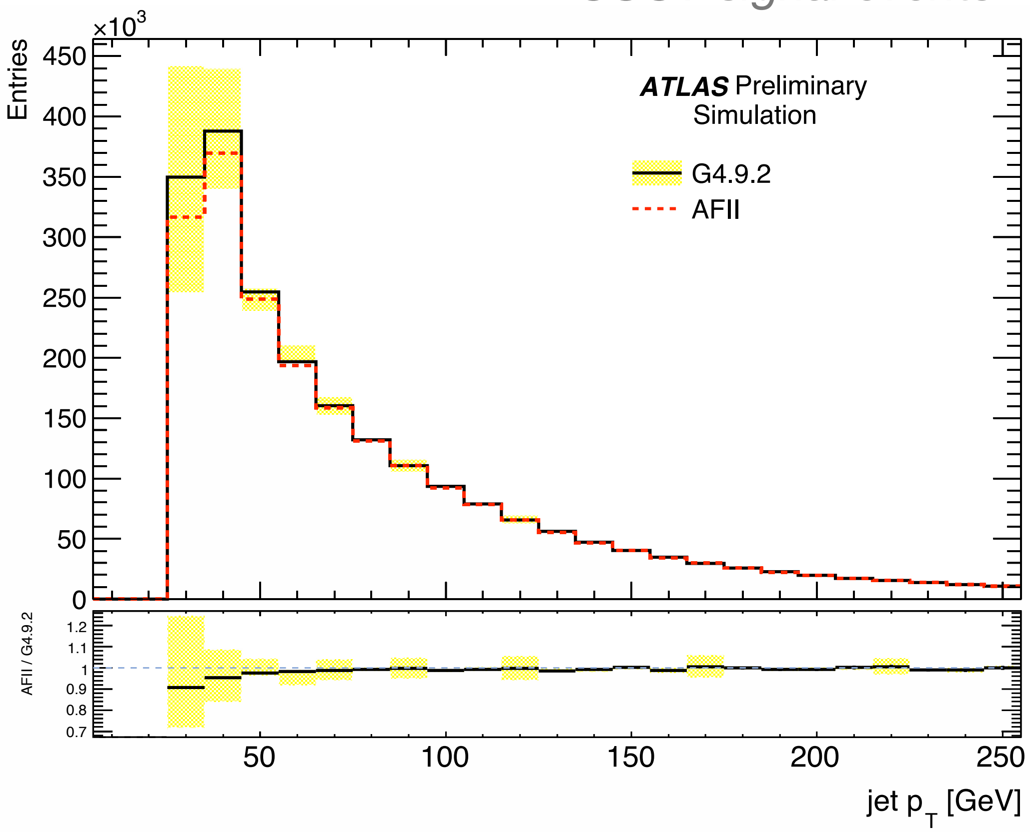


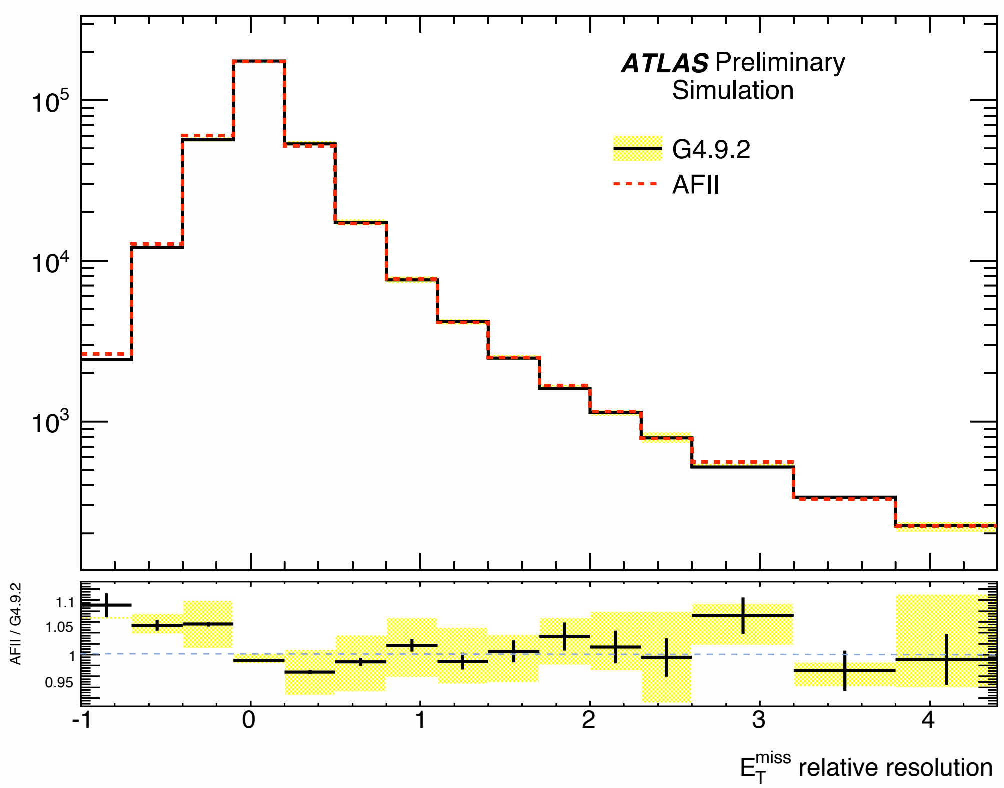
extensive validation performed for Geant4/AFII



Fast simulation ❖ AFII comparison to Geant4

SUSY signal events



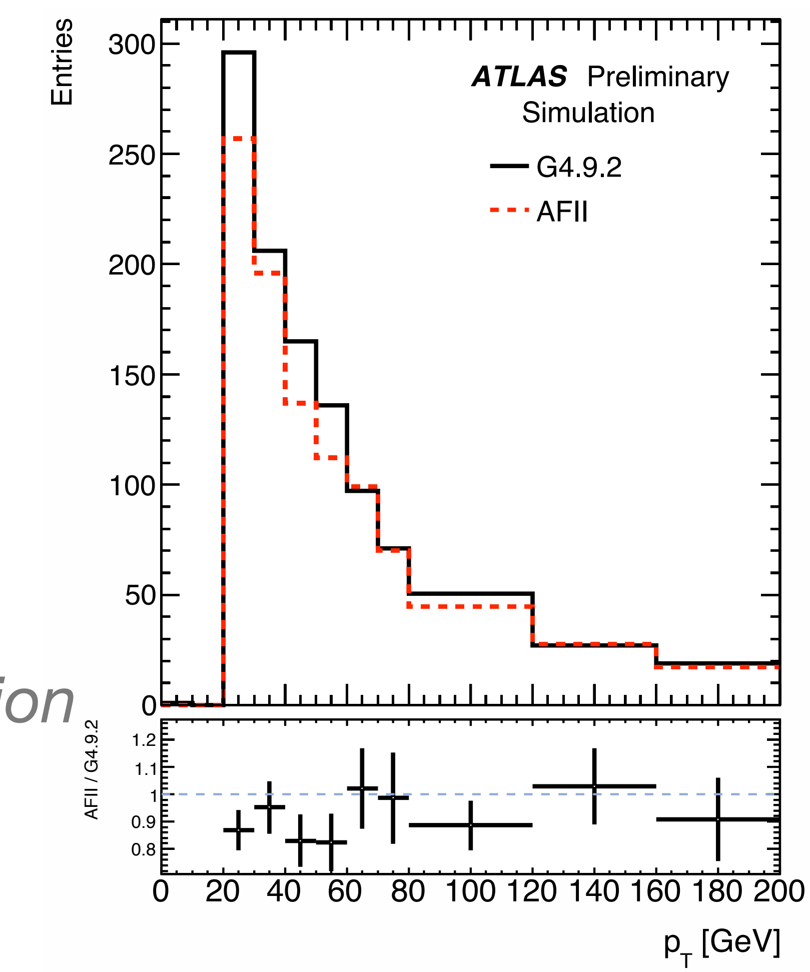


extensive validation in the context of SUSY analyses for summer 2011

AFII was found to be accurate enough within systematic of jet energy scale (5%)

part of the SUSY signal grid simulation of ~ 60 mio events done with AFII

p_T distribution of electron ***fakes***

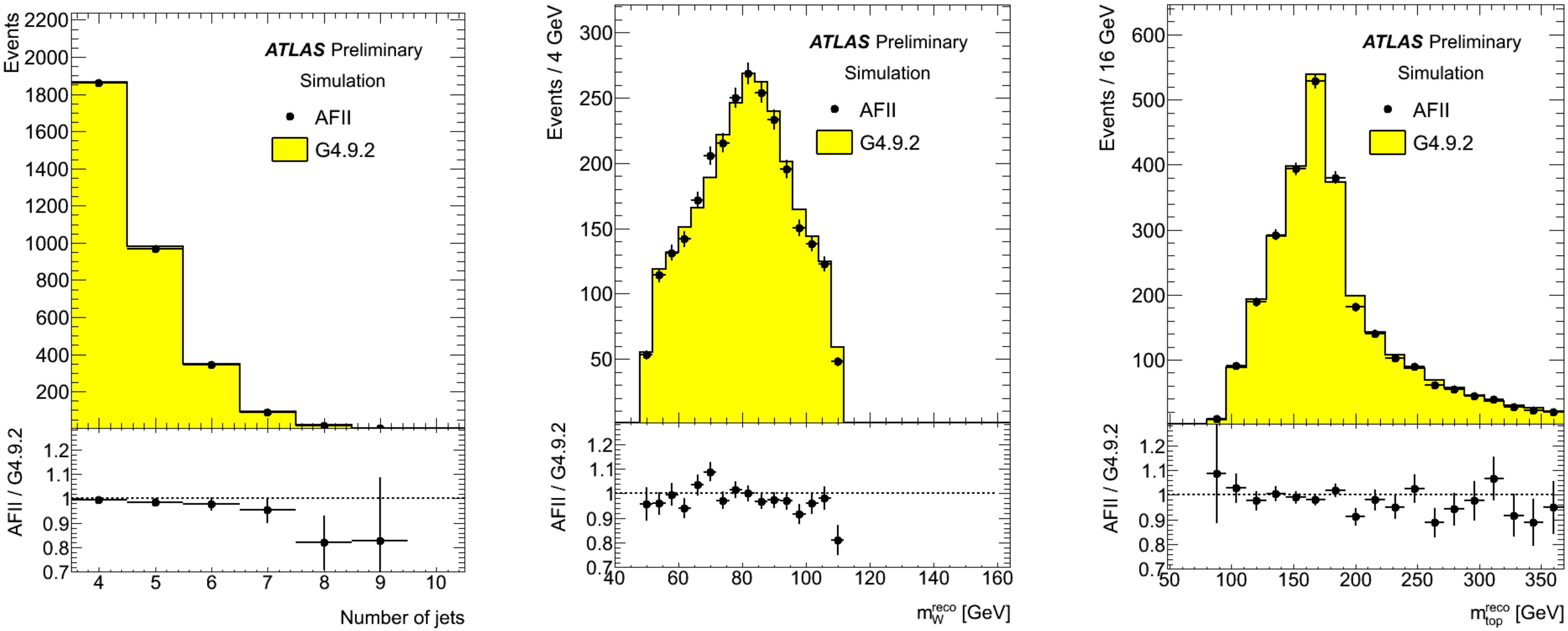


Fast simulation ❖ AFII comparison to Geant4

ATLFAST2 validation in context of top physics analyses

- number of jets, jet properties well reproduced

- reproduce m_W and m_{top} within statistical uncertainties

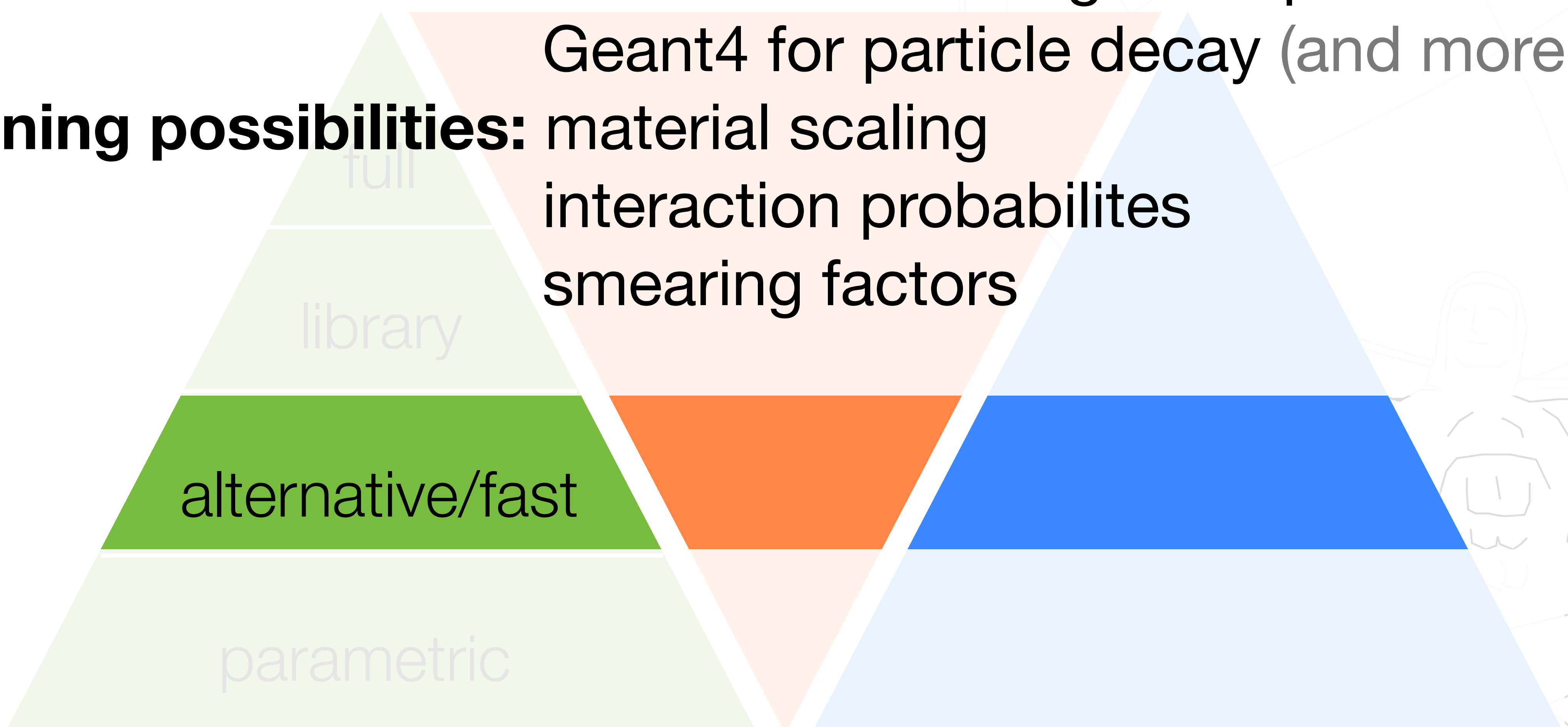


	e channel		μ channel	
	$N_{jets} \geq 4$	$N_b \geq 1$	$N_{jets} \geq 4$	$N_b \geq 1$
Full sim.	4735 ± 13	3202 ± 10	7012 ± 14	4780 ± 11
ATLFAST	4617 ± 45	3104 ± 38	7033 ± 53	4793 ± 42
Fast / Full	0.975 ± 0.010	0.969 ± 0.013	1.003 ± 0.008	1.003 ± 0.009

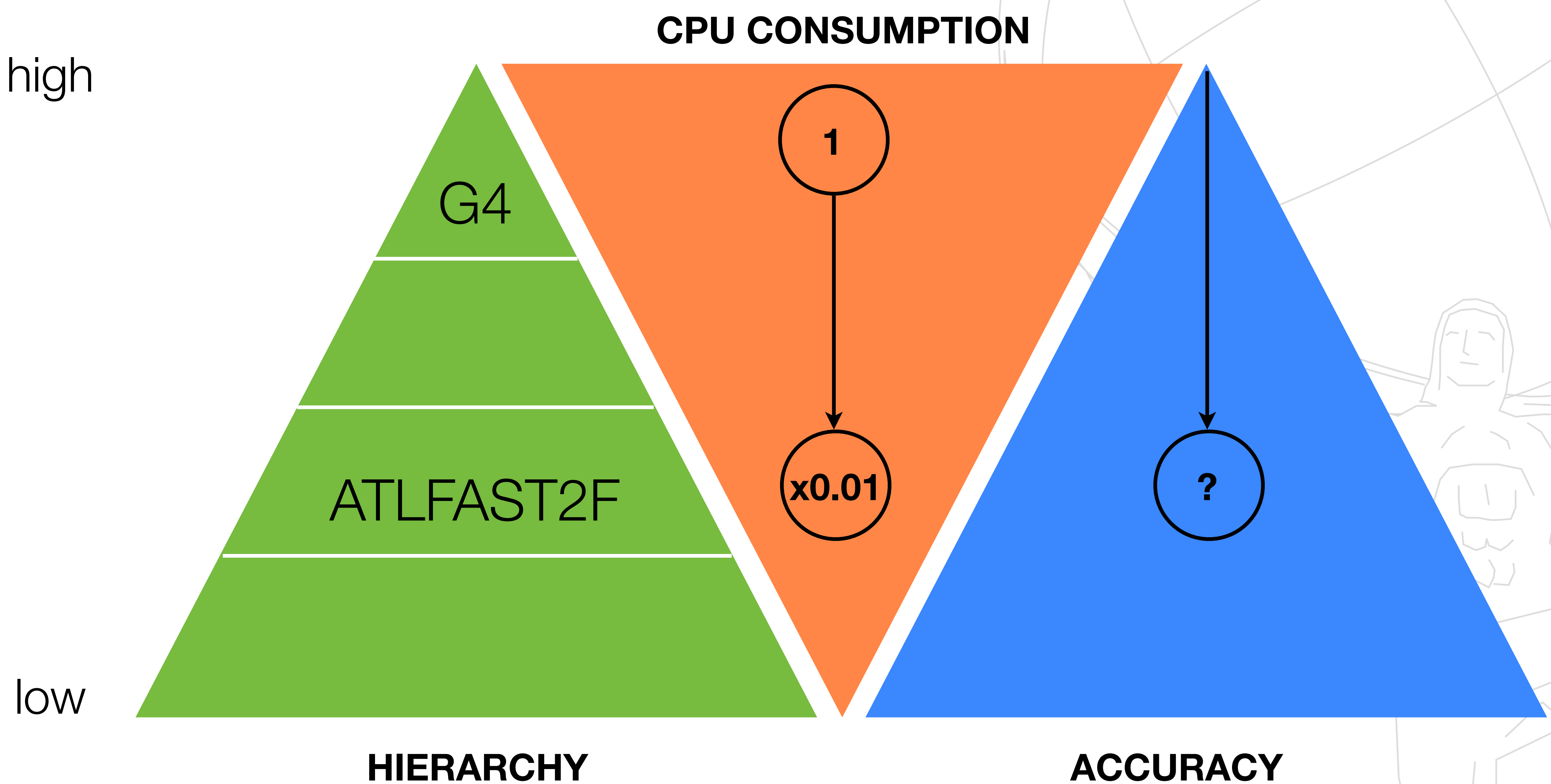
AFII jets being scaled by 1.0.1

Fast simulation in ID/MS ❖ FATRAS

geometry model: ATLAS TrackingGeometry
physics engine: ATLAS extrapolation (transport)
material effect integration parameterised
Geant4 for particle decay (and more ?)
tuning possibilities: material scaling
interaction probabilites
smearing factors



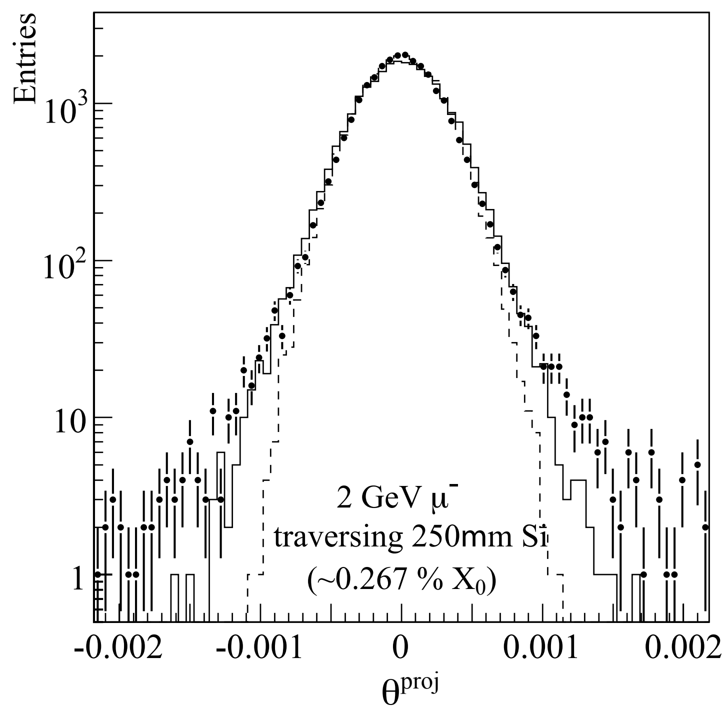
Fast simulation ❖ AFIIF



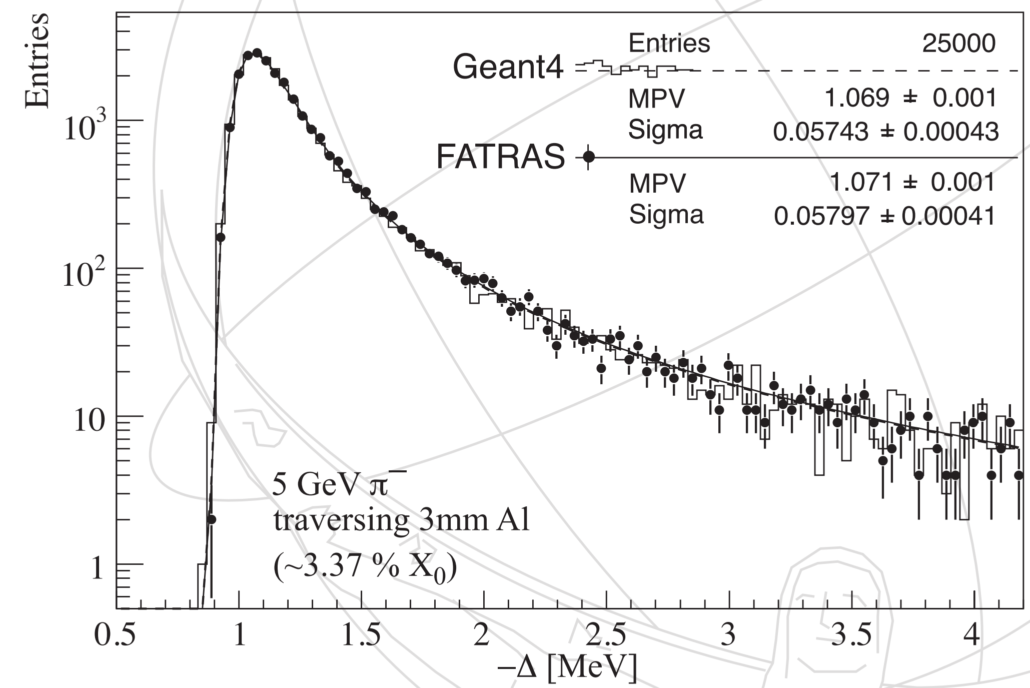
Fast simulation in ID/MS ❖ FATRAS

Parameterisation of material interactions

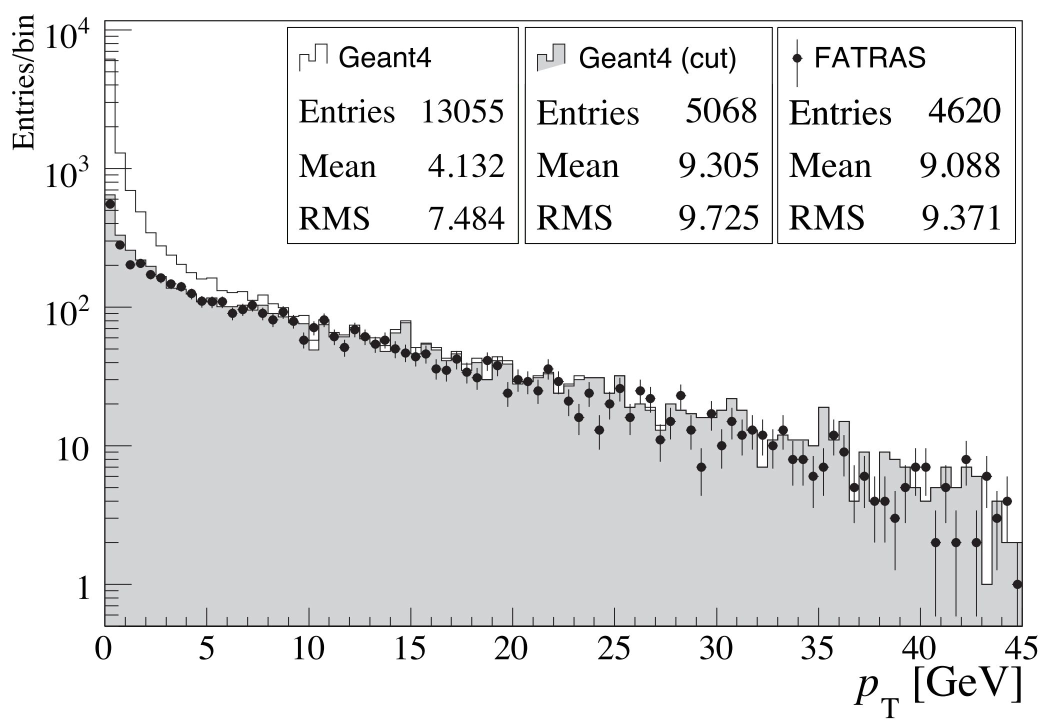
(a) multiple scattering



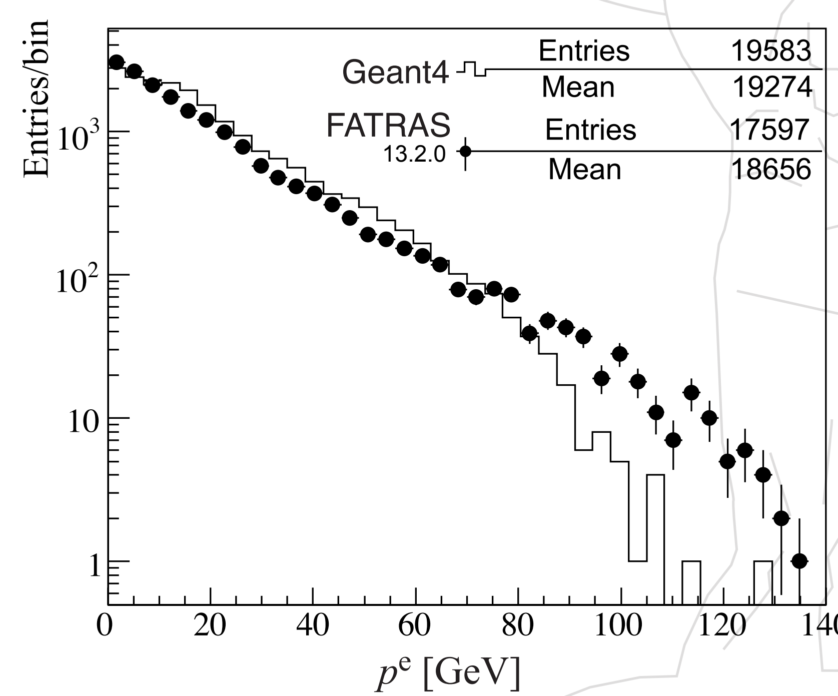
(b) ionisation energy loss



(c) brem photon radiation

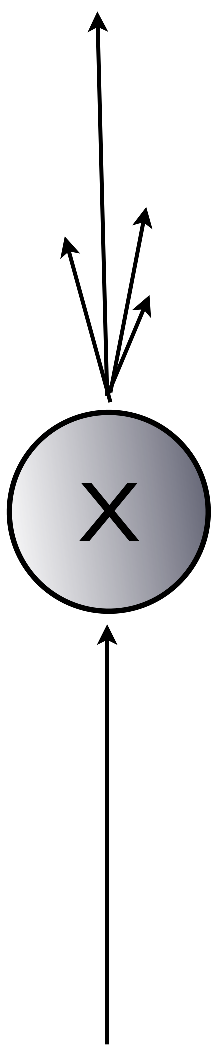


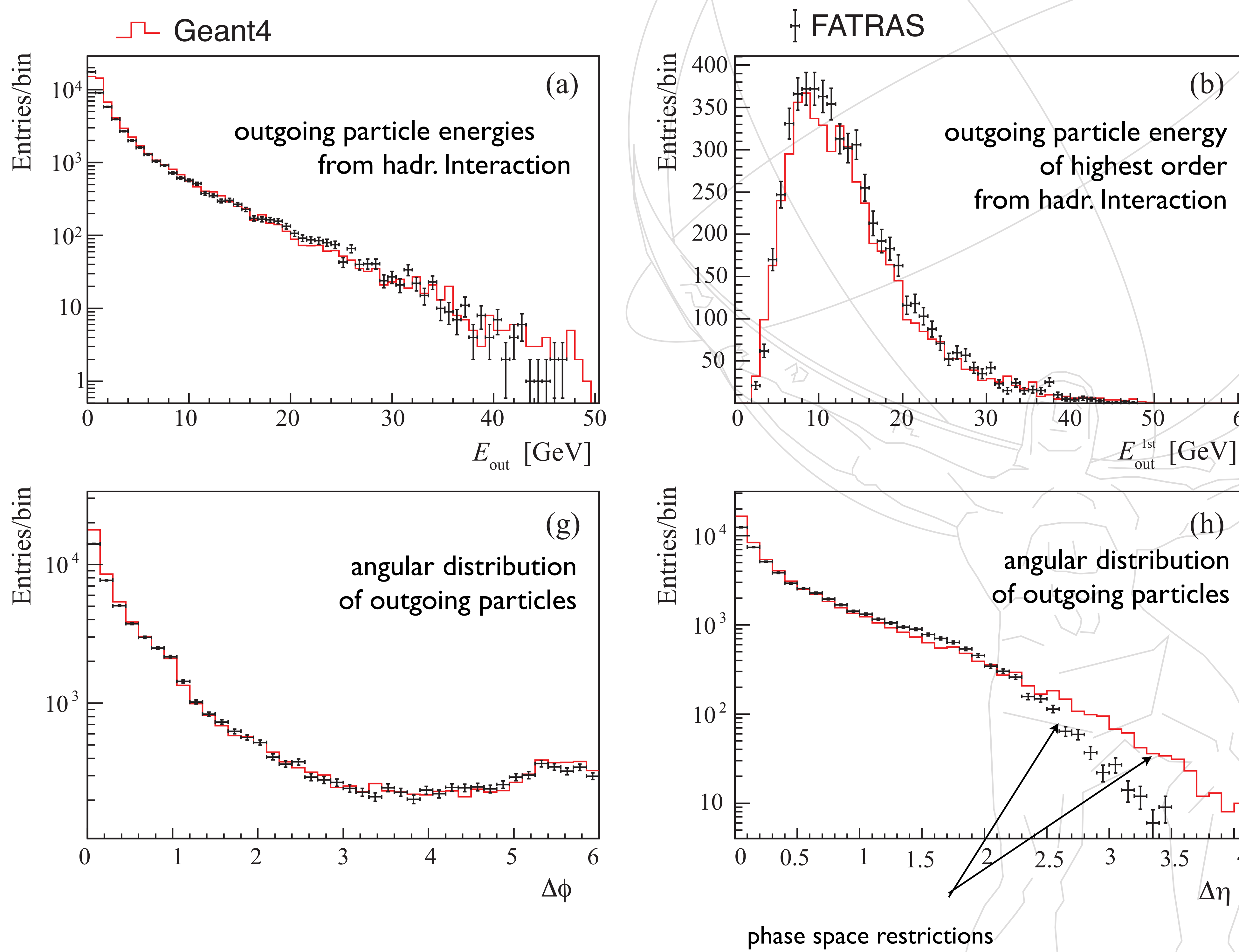
(d) brem photon conversion



Fast simulation in ID/MS ❖ FATRAS

(e) nuclear interactions (parametric model implemented)



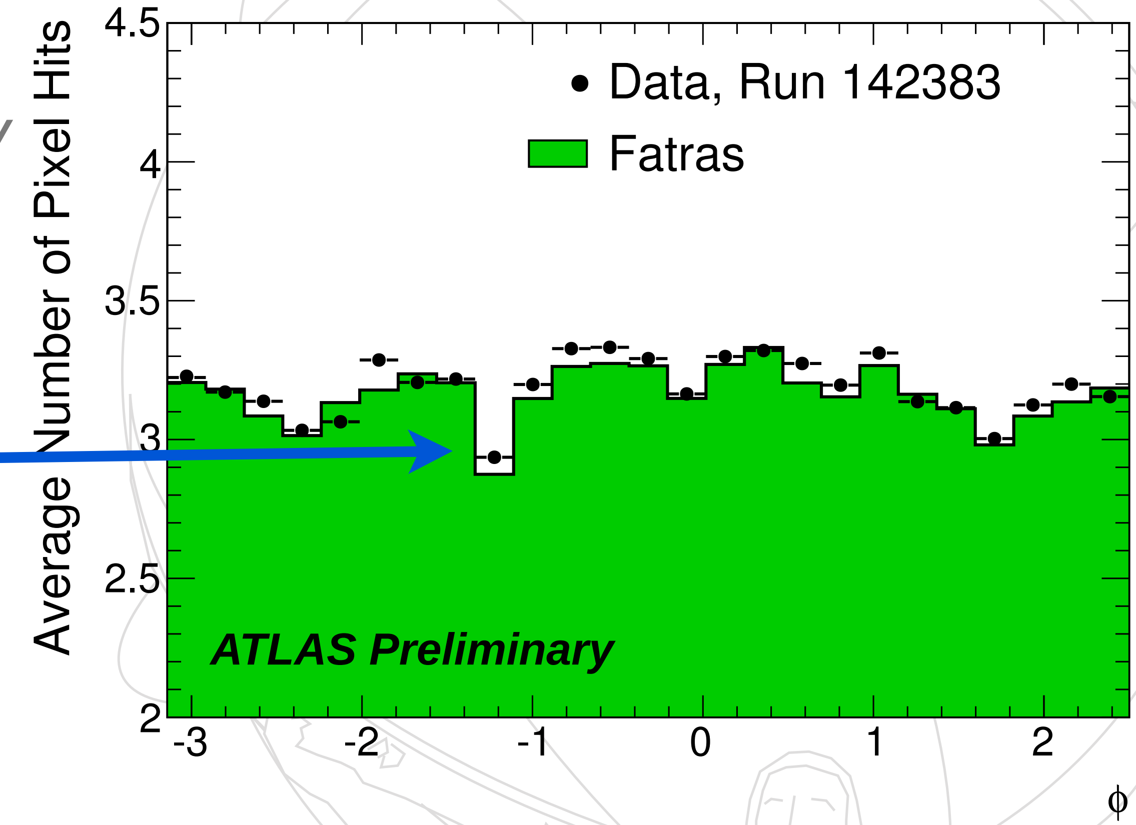


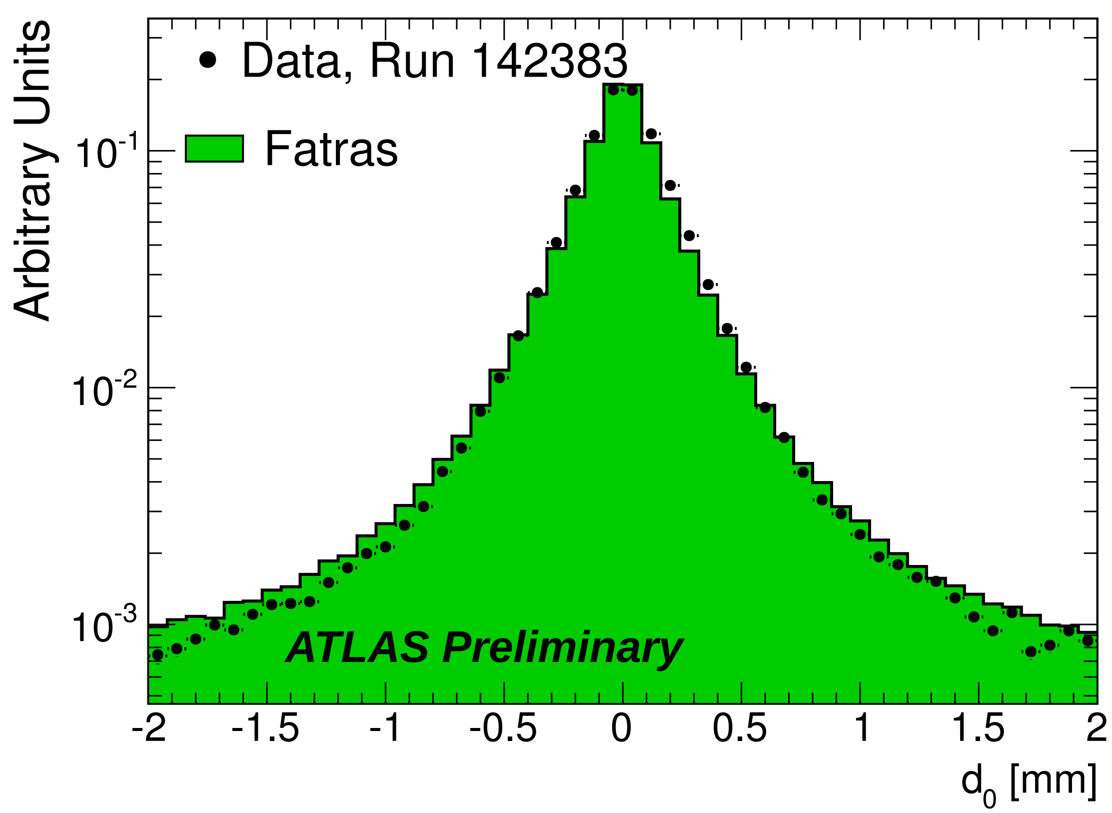
Fast simulation in ID/MS ❖ FATRAS

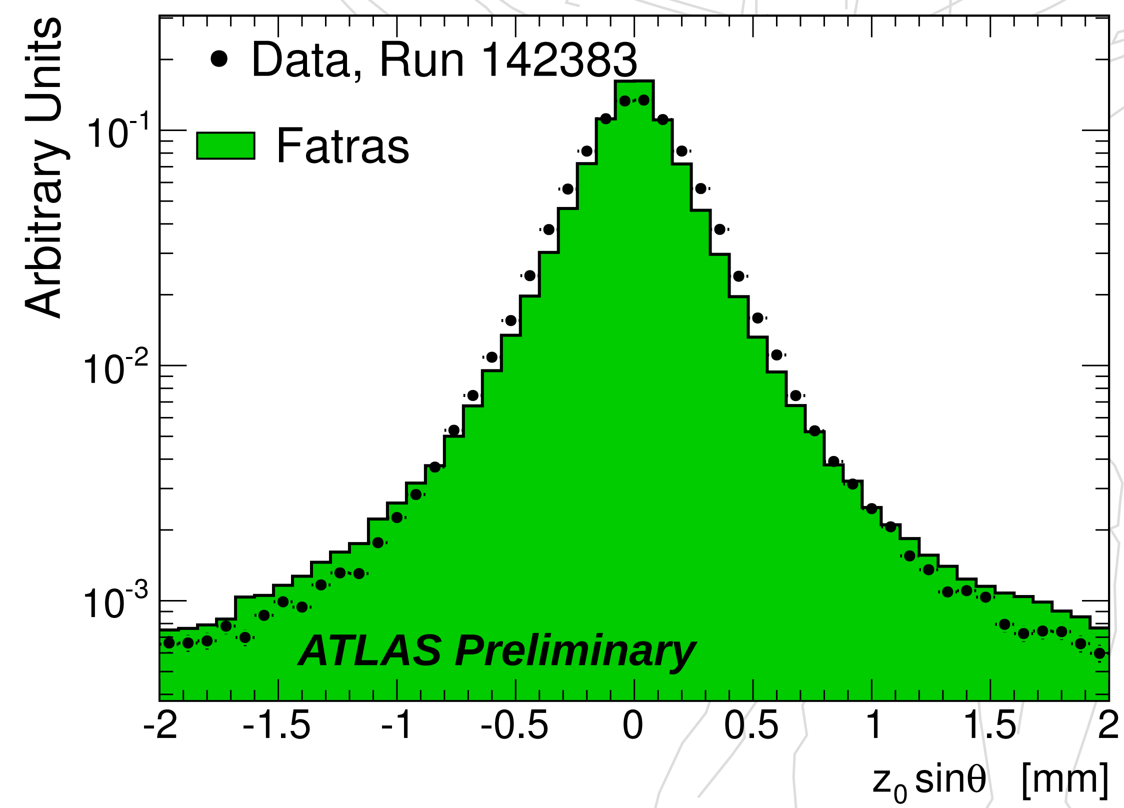
FATRAS in comparison to data

- ID reconstruction, tracks with $p_T > 500$ MeV

- using exact same sensitive detector elements:
conditions data being fully integrated

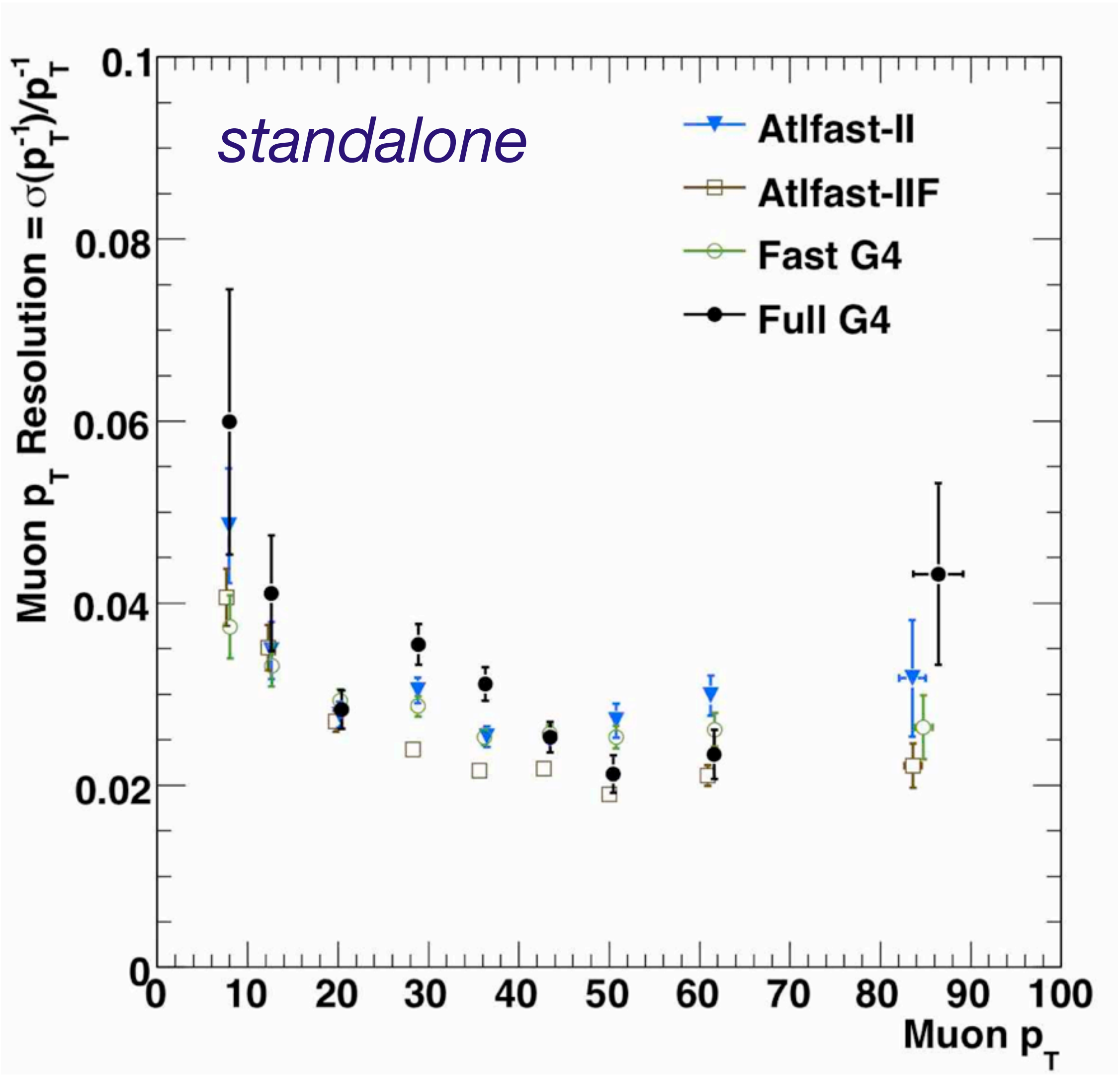


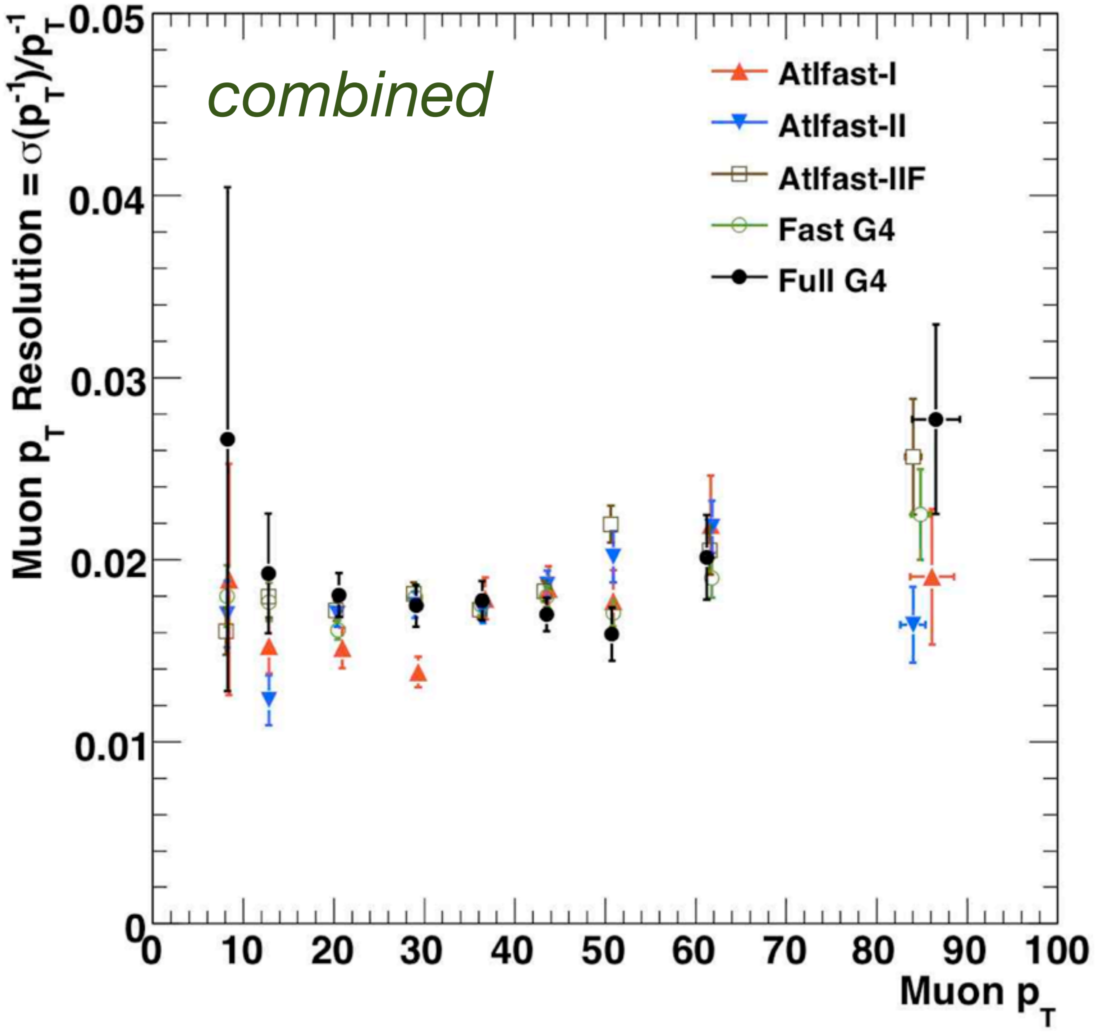




Fast simulation in ID/MS ❖ AFII/AFIIF

- *ATLAS standalone Muon System and combined (ID/MS) muon reconstruction*

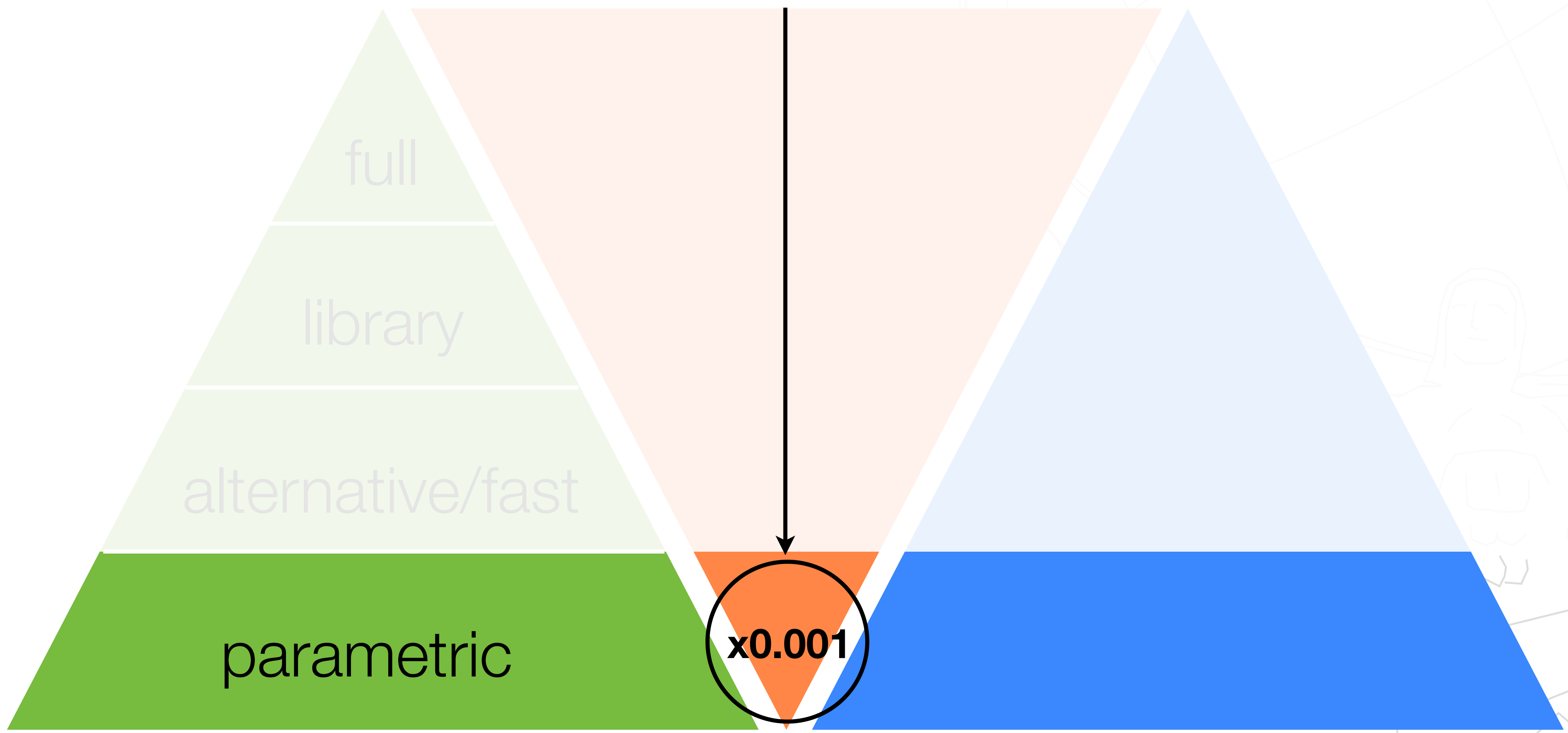


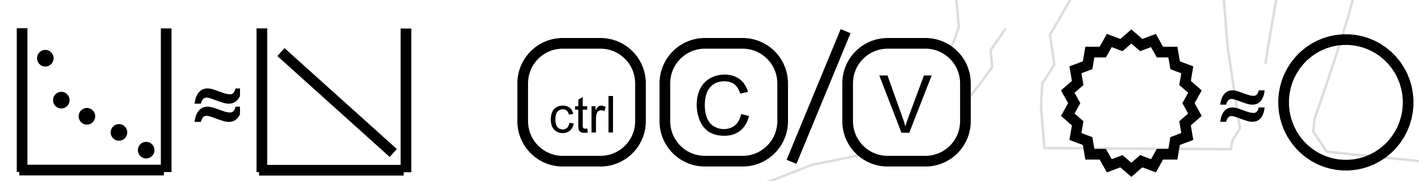


Fast simulation ❖ ATLFAST

Fully parametric simulation

- smearing approach to create physics objects (no reconstruction)
- has been used in the TDR phase of ATLAS





Fast simulation ❖ ATLFAST

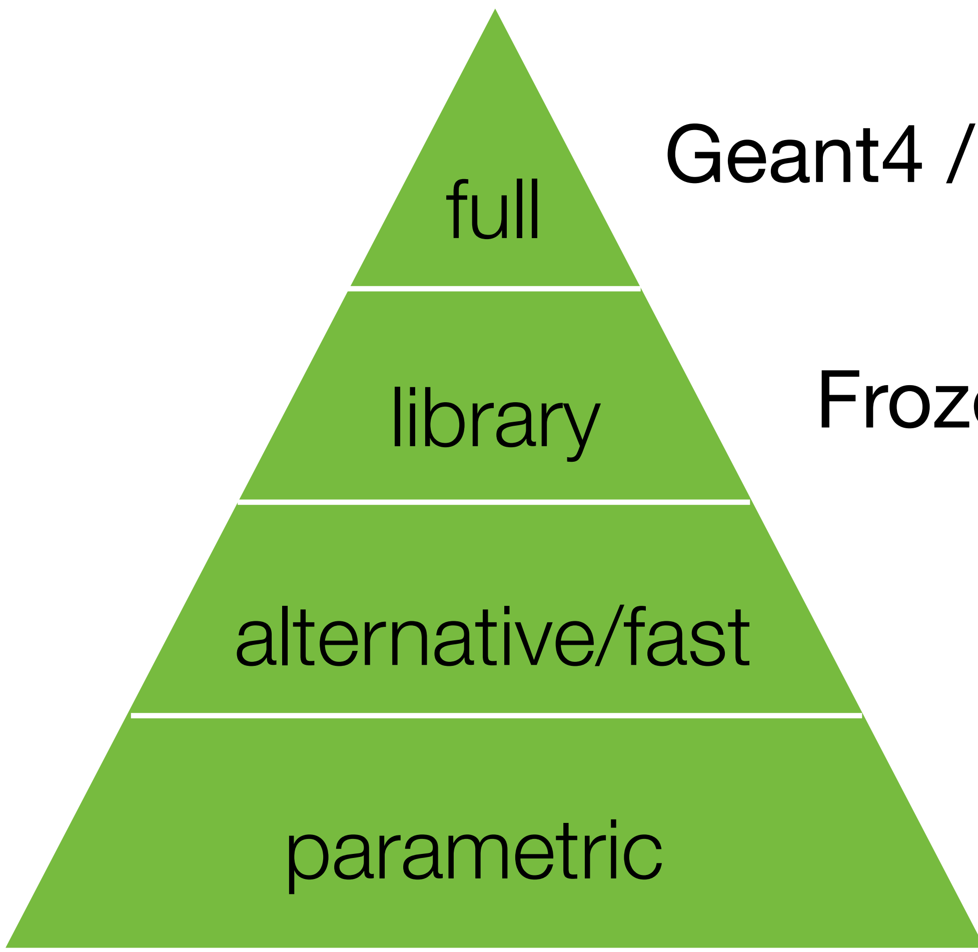
Long experience in ATLAS using parametric simulation

- *extremely fast*
- *no efficiencies/fakes*
- *no pile-up effects*
- *however, often requested by theorists/externals, generic applications on the market (e.g. Delphes)*

Is parametric smearing something we (as a community) want to provide ?

ATLAS prefers to publish unfolded fiducial measurements to a parameteric public simulation.

Recap



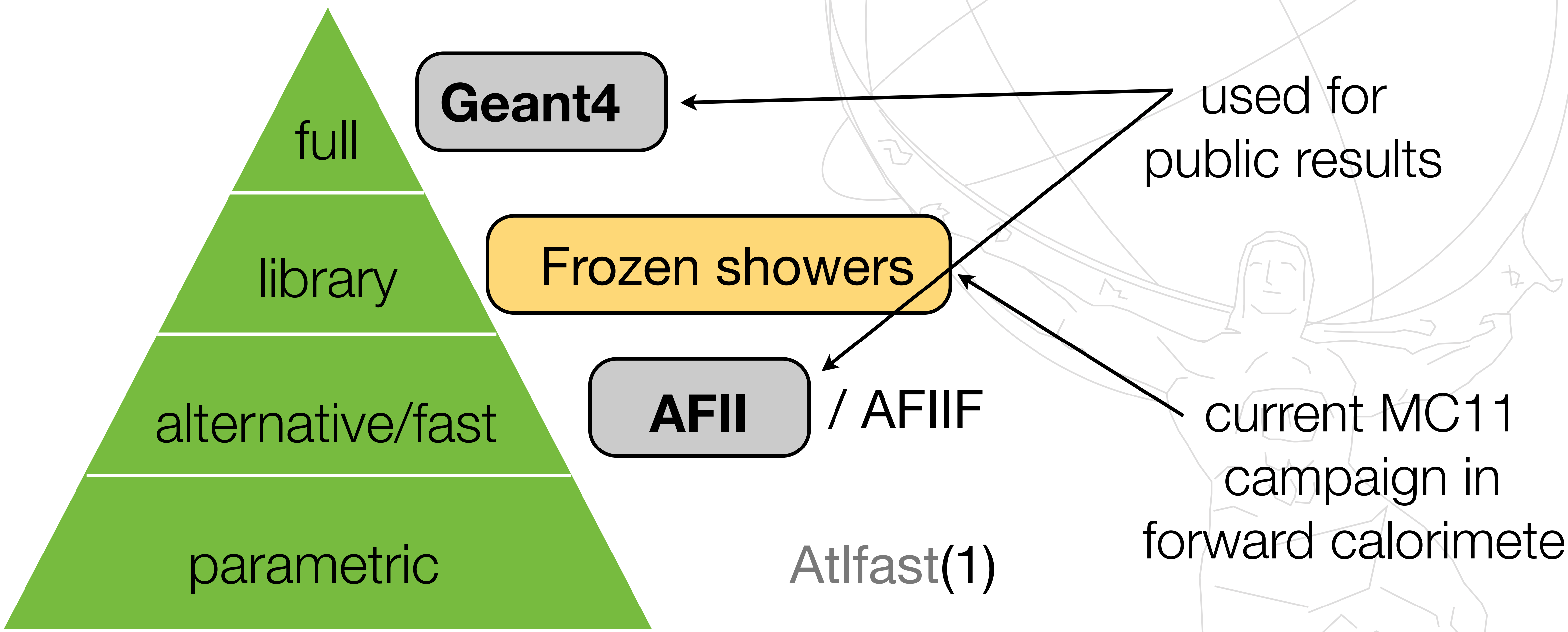
Geant4 / Fluka (Flugg) / Geant3

Frozen showers

AFII / AFIIF

Atlfast(1)

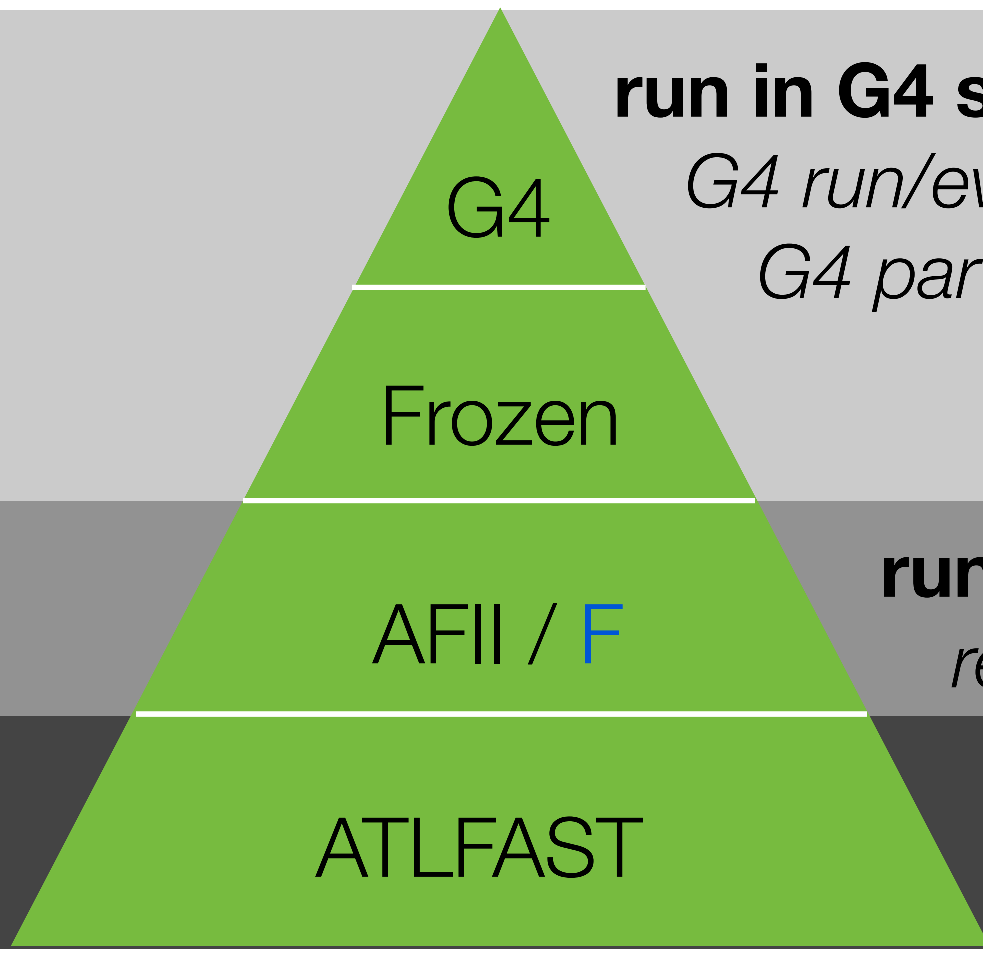
Recap



full
library
alternative/fast
parametric
Geant4
Frozen showers
AFII
/ AFIIF
Atlfast(1)
used for
public results
current MC11
campaign in
forward calorimeter

Recap

All simulation setups run in Athena



run in G4 setup:

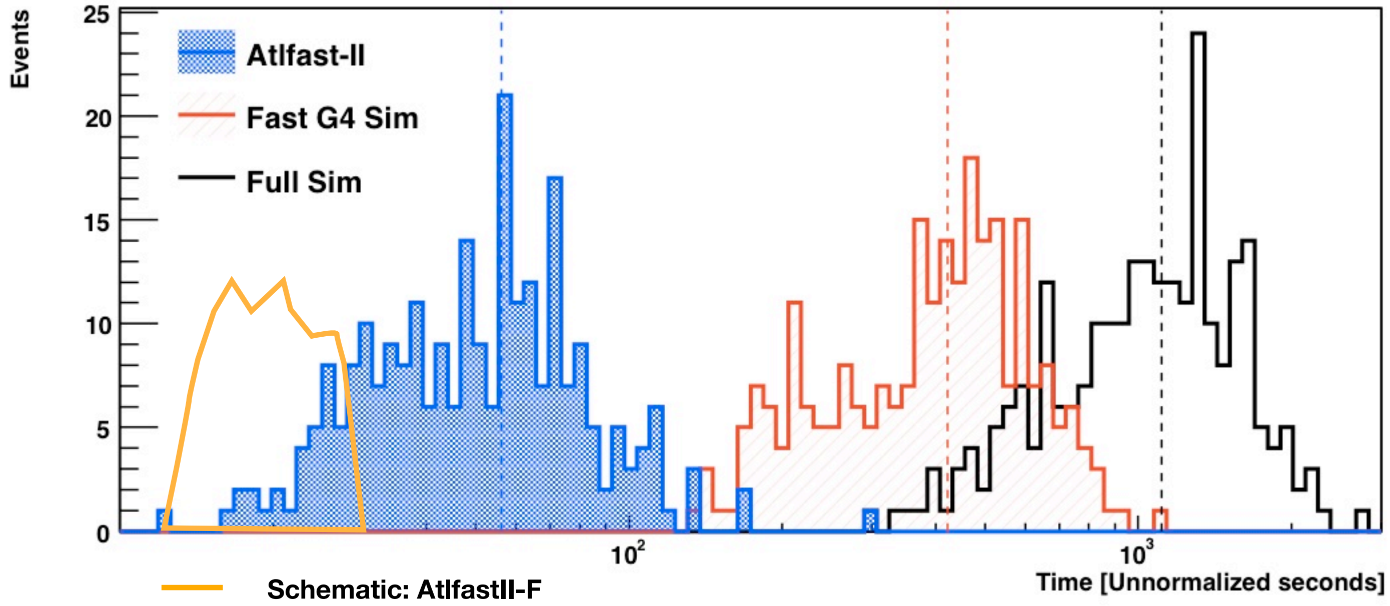
G4 run/event handling

G4 particle stack

run in G4/FATRAS setup:

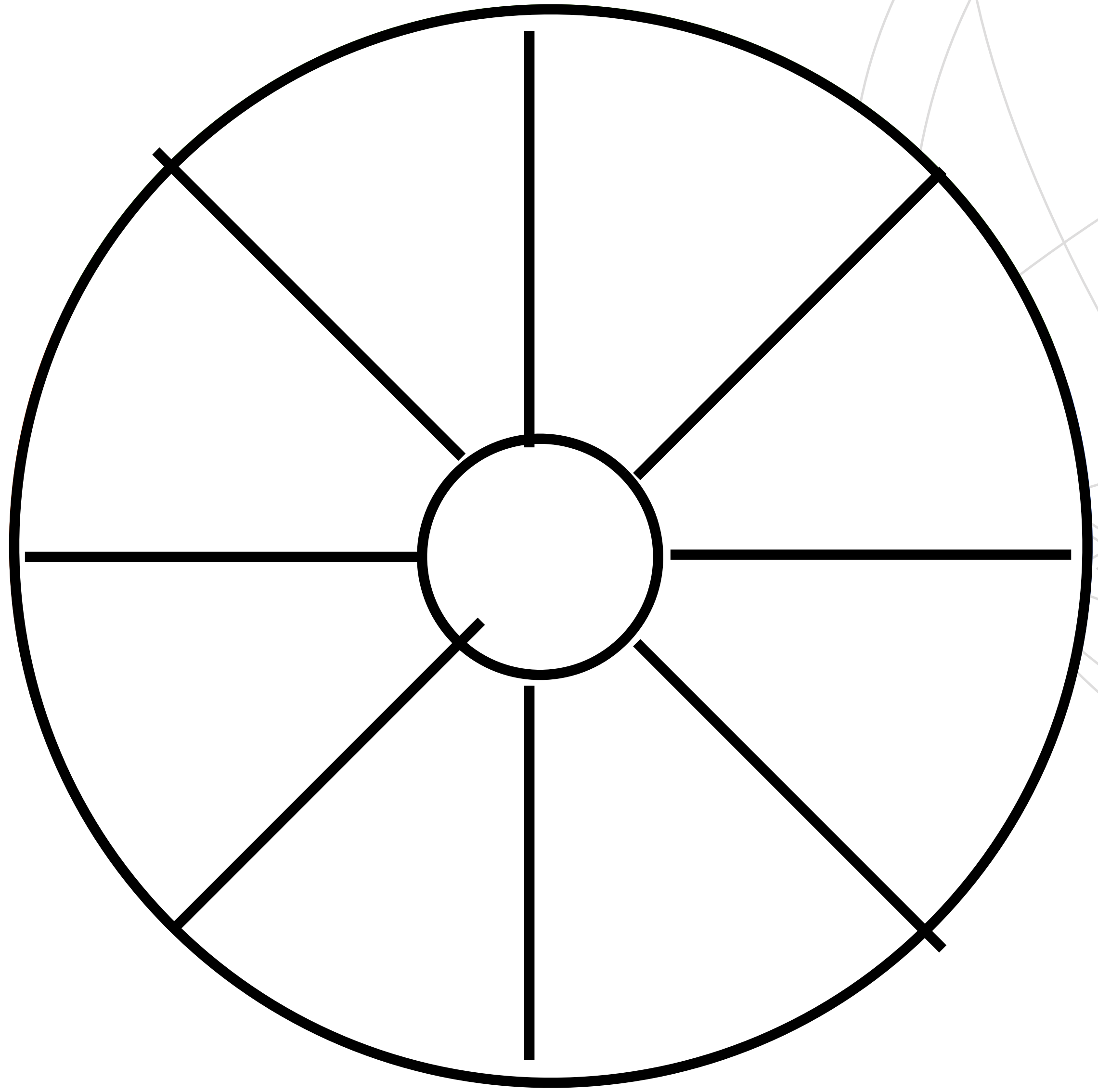
requires 2/1 simulation job

runs in ATLFAST setup

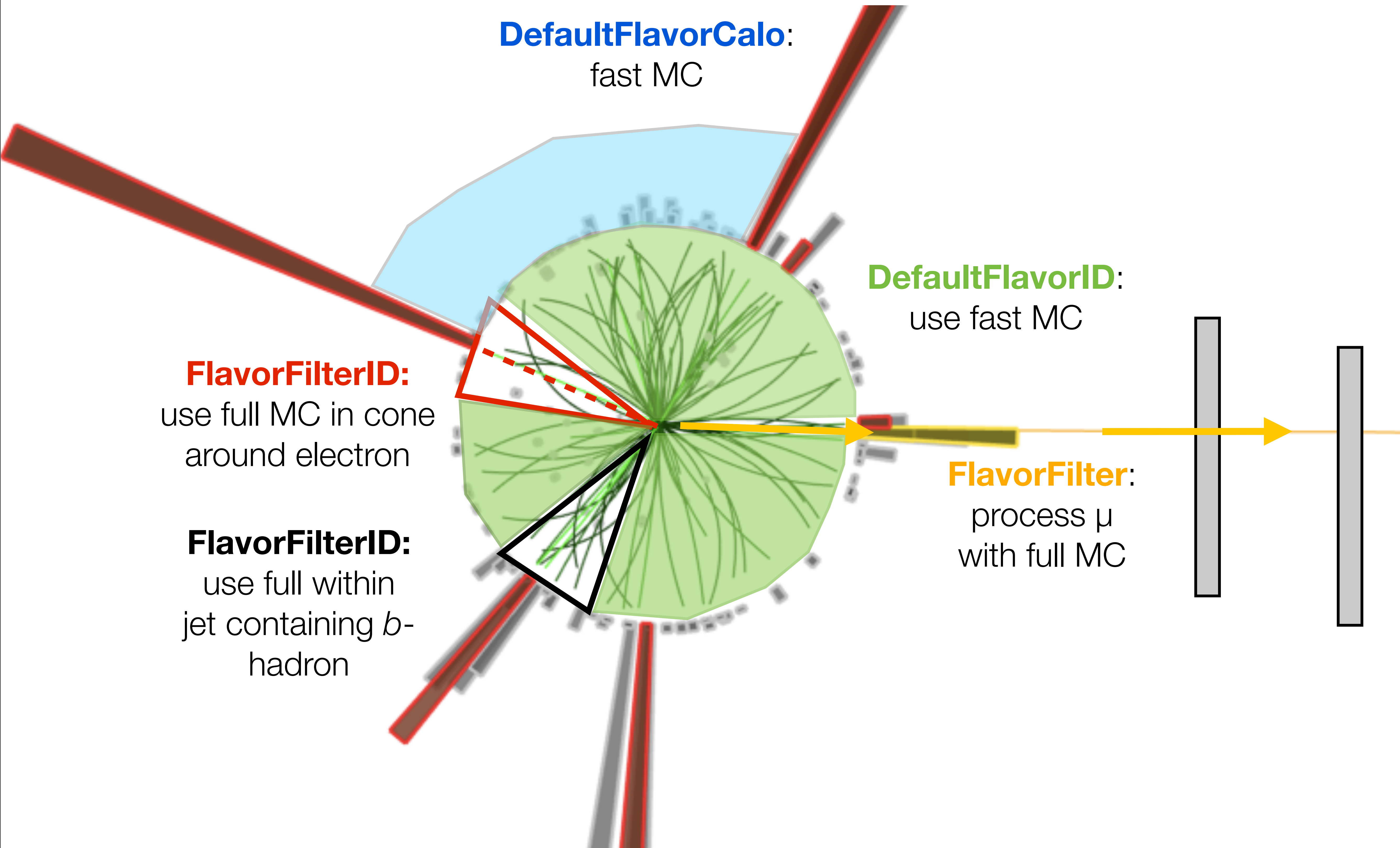

Events
25
20
15
10
5
0
Atlfast-II
Fast G4 Sim
Full Sim
10^2
10^3
Time [Unnormalized seconds]
Schematic: AtlfastII-F

The Integrated Simulation Framework

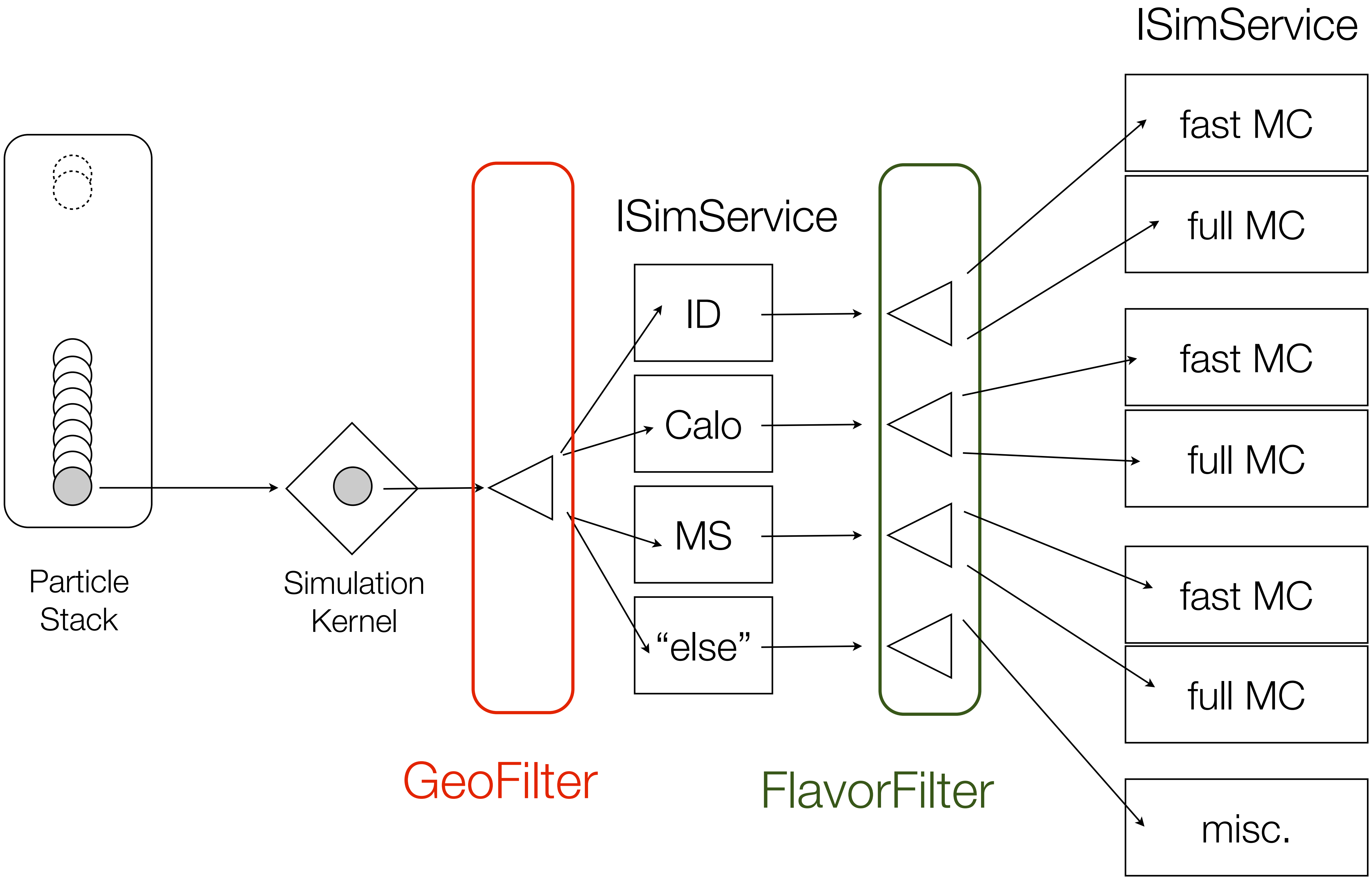
The Integrated Simulation Framework



The nutshell ISF vision



The nutshell ISF design

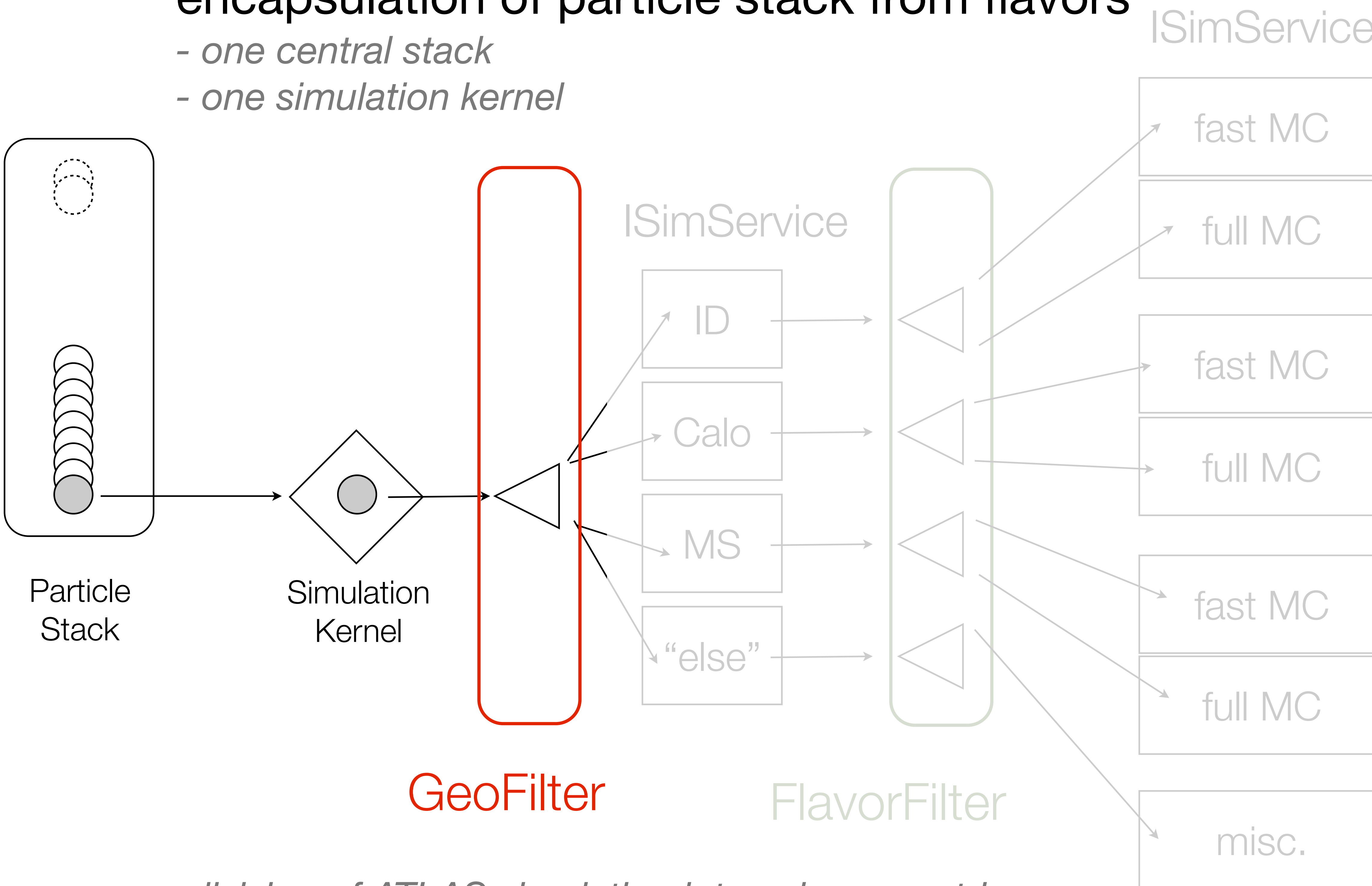


The nutshell ISF design

encapsulation of particle stack from flavors

- one central stack

- one simulation kernel

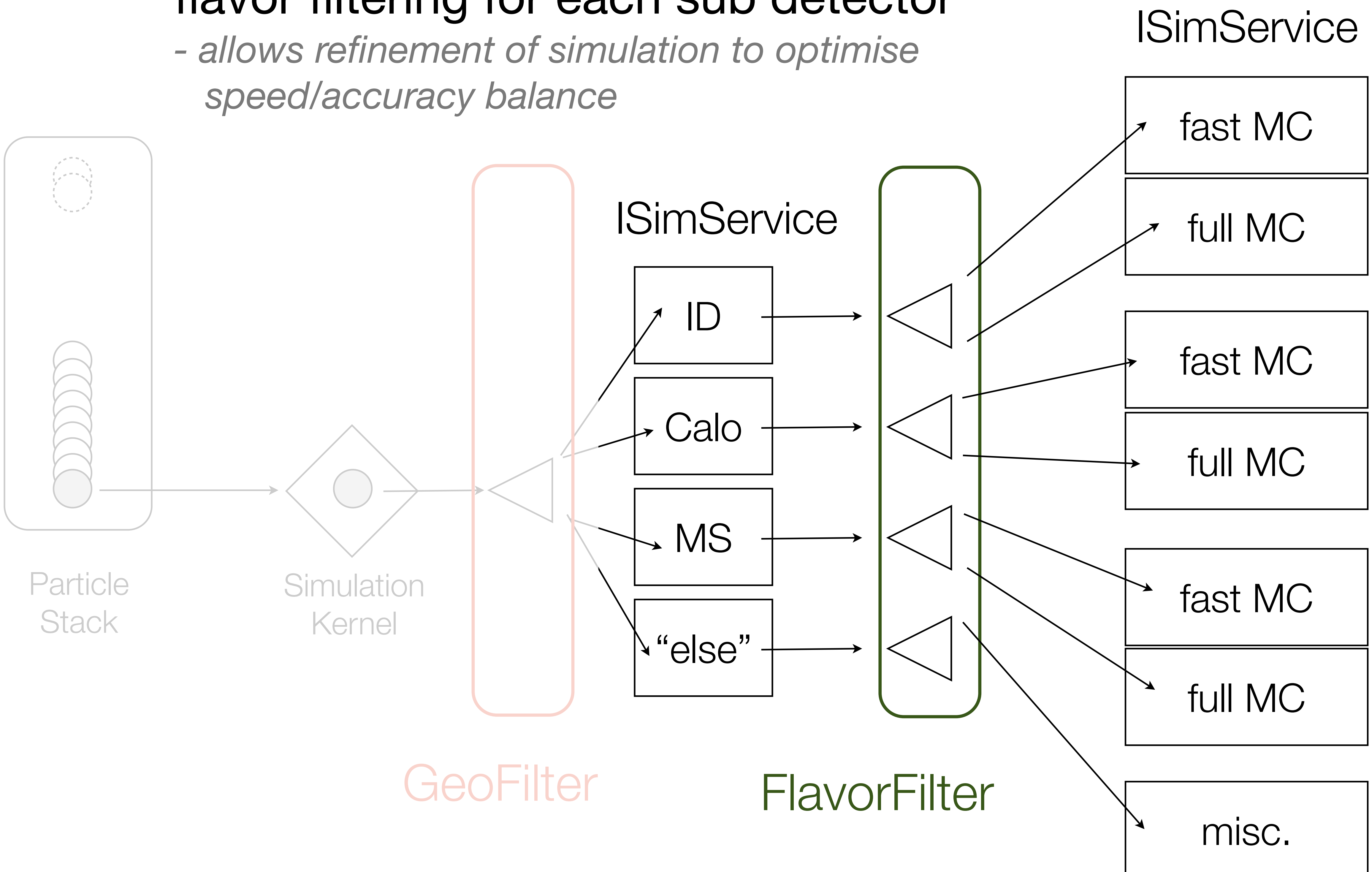


- division of ATLAS simulation into sub-geometries

The nutshell ISF design

flavor filtering for each sub detector

- allows refinement of simulation to optimise speed/accuracy balance



- flexibility to integrate new simulation flavors
- prepare for parallel particle processing

The nutshell ISF design & prototype

encapsulation of common services defined by interfaces

- event handling, stack handling, truth filling, hit recording, barcode creation

aim to feed central hit collection from ISF flavors

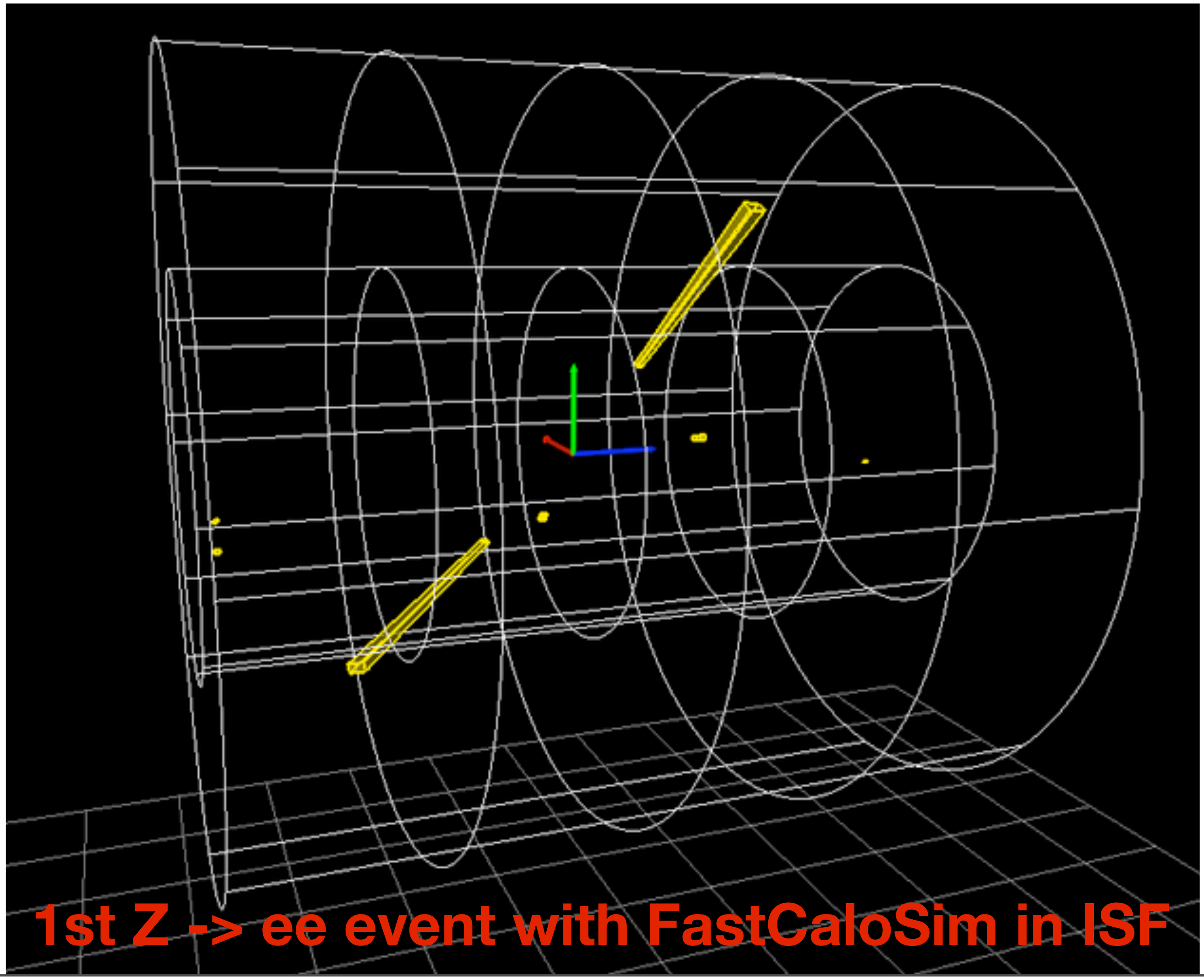
- to allow for common pile-up digitization

FastCaloSim & FATRAS have been imported to the prototype

- first simulation tests running
- we want to gather experience how to mix simulation flavors

Geant4 interfacing on the way

- Geant4 can/will still keep an internal particle stack
- learn how to feed a future parallel simulation flavor



ISF benefits ❖ mix and play

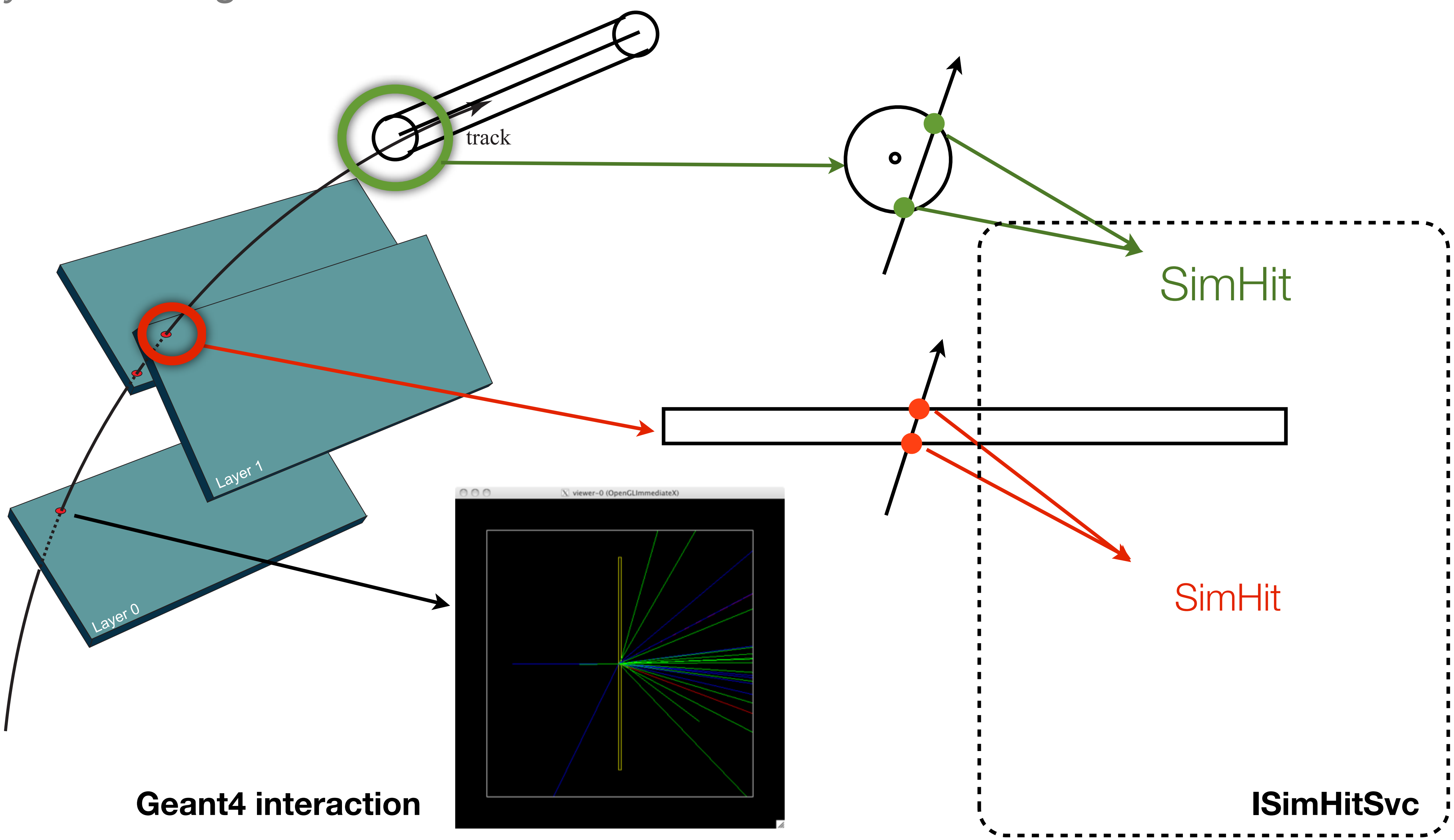
A common hit service in the ISF

- AFII creates already "SimHit" objects similar to Geant4 hits

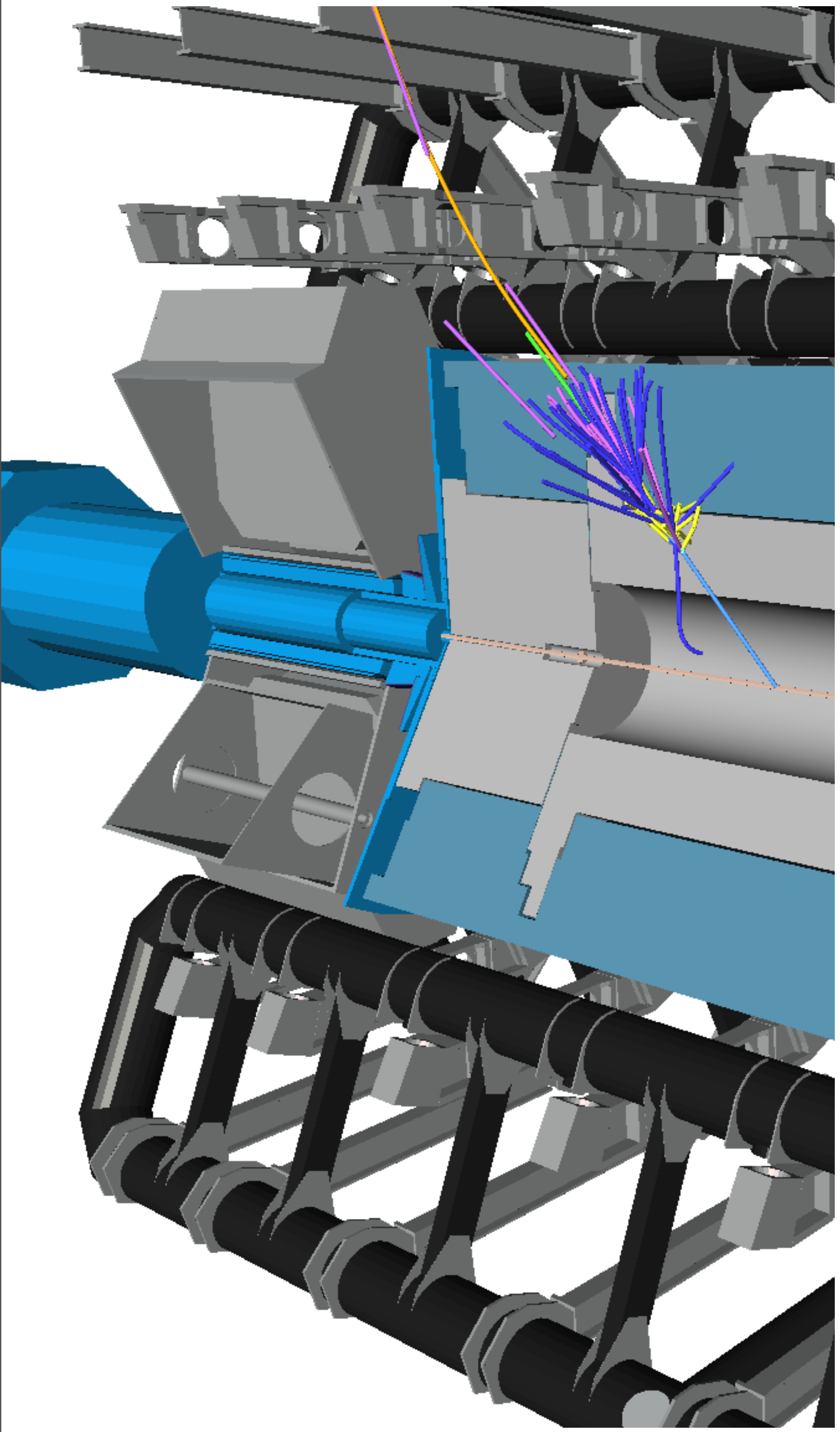
plan to update FATRAS in Inner Detector

- implemented parameterized material effects → ISF: use Geant4

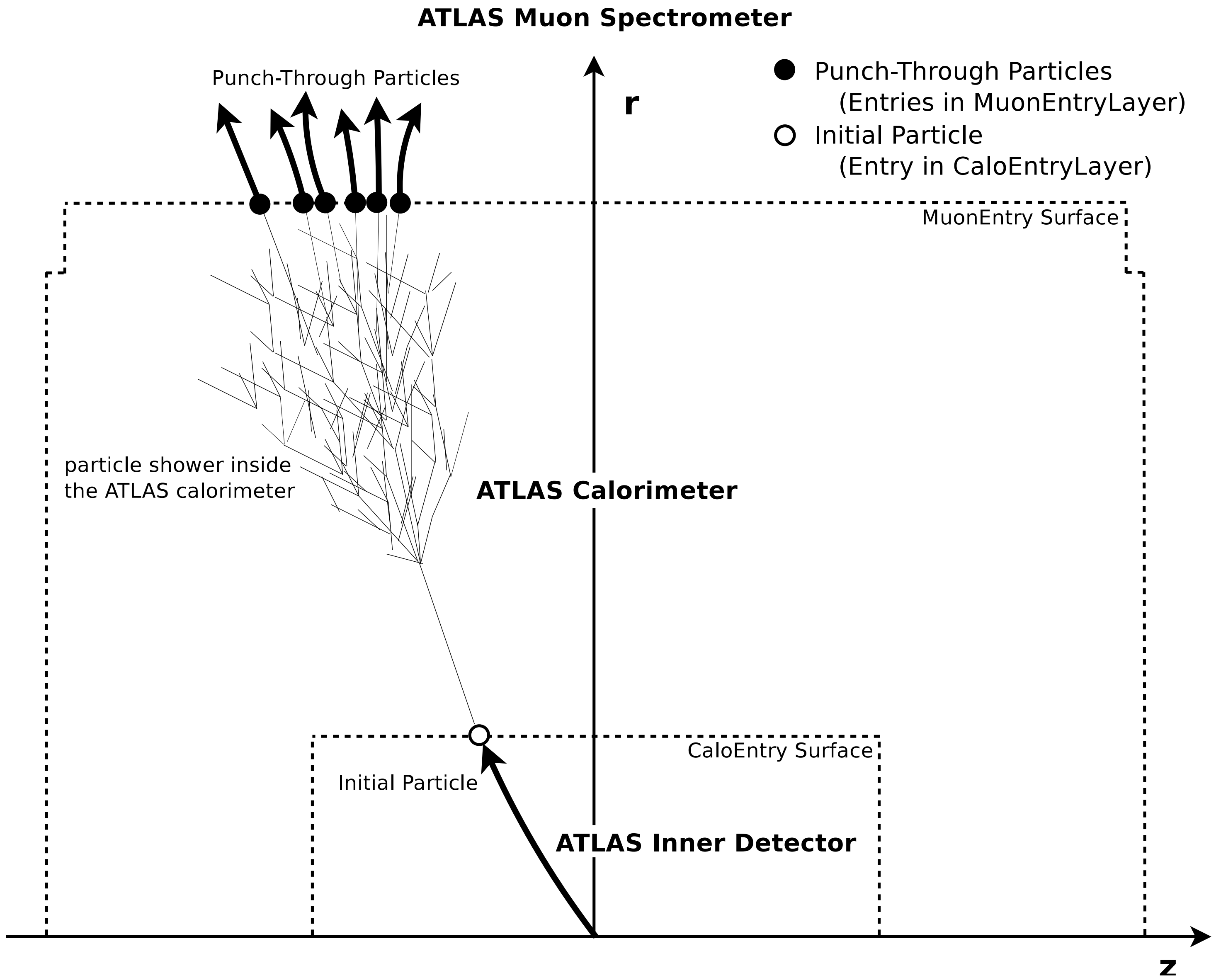
- did not deploy ATLAS digitization model → ISF: create hits like Geant4



ISF benefits ❖ extend easily



new parameterisation of hadronic leakage into the Muon System



ATLAS fast simulaton ❖ today & tomorrow

ATLAS has extremely profited from Geant4 simulation

- close collaboration with Geant4 community is extremely profitable

ATLAS has a long-standing experience with fast simulation

- starting from ATLFAST in TDR times
- first AFII used in public results for summer conferences 2011
- bulk production of AFII samples in new MC11 campaign

Currently fast/full simulation require different setups

Huge effort started to develop an integrated simulation framework

- steer all simulation flavors from one single framework
- vision: mix fast and full MC techniques in one single event
- feedback this experience into simulation R&D for the future (long-term)

Backup section

Timing Tables

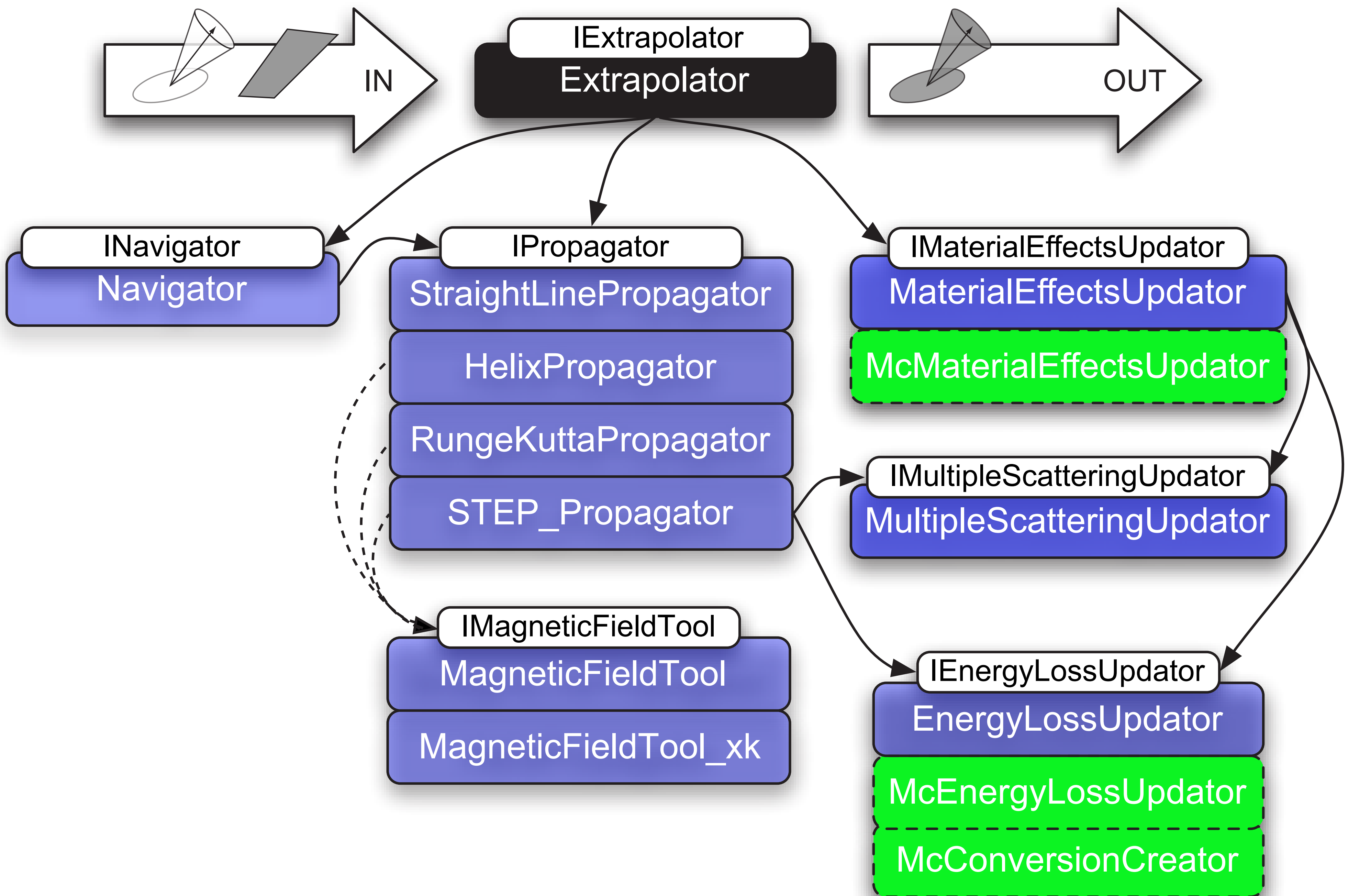
Sample	**Full G4 Sim**	**Fast G4 Sim**	**Atlfast-II**	**Atlfast-IIF**
Minimum Bias	551.	246.	31.2	2.13
$t\bar{t}$	1990	757.	101.	7.41
Jets	2640	832.	93.6	7.68
Photon and jets	2850	639.	71.4	5.67
$W^{\pm} \rightarrow e^{\pm}\nu_e$	1150	447.	57.0	4.09
$W^{\pm} \rightarrow \mu^{\pm}\nu_\mu$	1030	438.	55.1	4.13

Table 1: Simulation times per event, in kSI2K seconds, for the full Geant 4 simulation, fast Geant 4 simulation, Atlfast-II, Atlfast-IIF [4]. Atlfast-II uses the full simulation for the inner detector and muon system and FastCaloSim in the calorimetry. Atlfast-IIF uses FastCaloSim for the calorimetry and FATRAS for the inner detector and muon system. All times are averaged over 250 events.

TABLE I: Average time required for production of simulated hits for single muon samples in ATLAS MuonSpectrometer.

Simulated hit creation (MS only)	Geant4 [s/event]	FATRAS [s/event]
p_T=10GeV	0.13±0.01	0.015±0.002
p_T=100GeV	0.17±0.02	0.015±0.002

ATLAS/FATRAS extrapolation engine



ATLAS/FATRAS extrapolation engine