UNIVERSITÉ
DE GENÈVE

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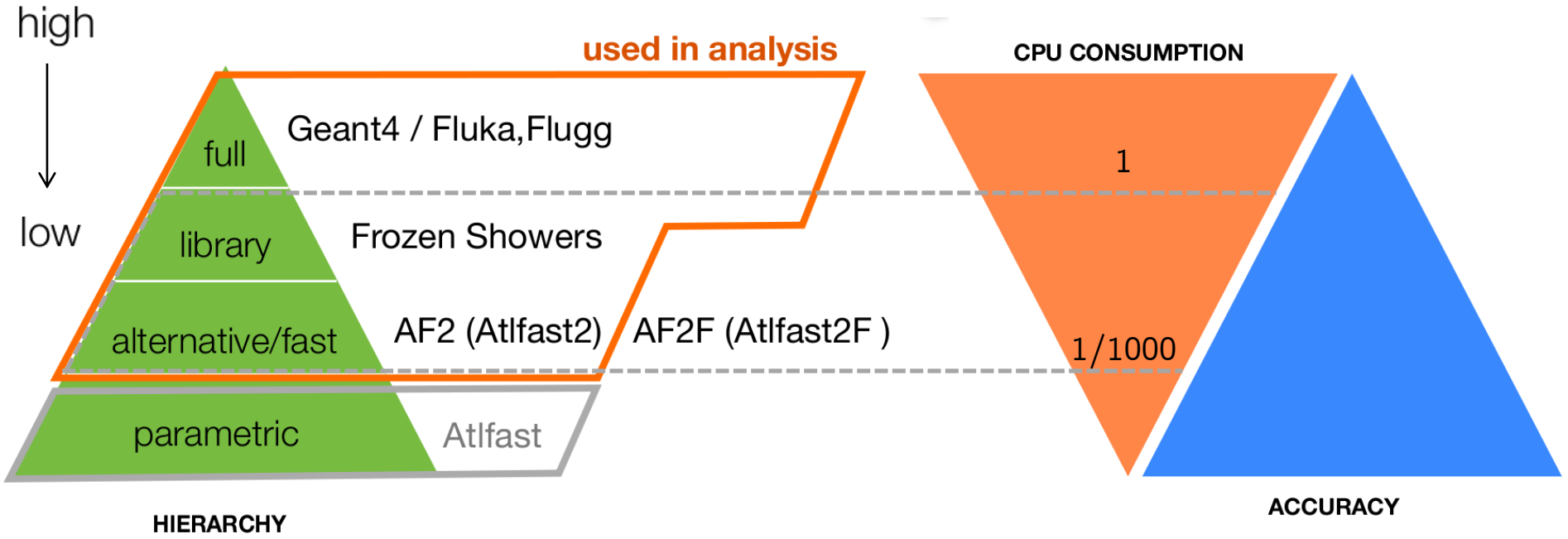
Student presentation @ CHIPP PhD Winter School 2015

22 January 2015

Fast Simulation in ATLAS for Upgrade Studies

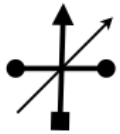
The simulation history in ATLAS (until recently)



*The picture is quite trivial, finding the optimal working point is NOT!

Fast simulation - Ways to speed up simulation

approximate geometry



optimise transport and navigation

$\pi \approx 3$

approximate models

parameterisations

take shortcuts

use new technologies

don't do anything

work only on demand

use look-up tables

throw away things

...

Fast Simulation – AFIIF/G

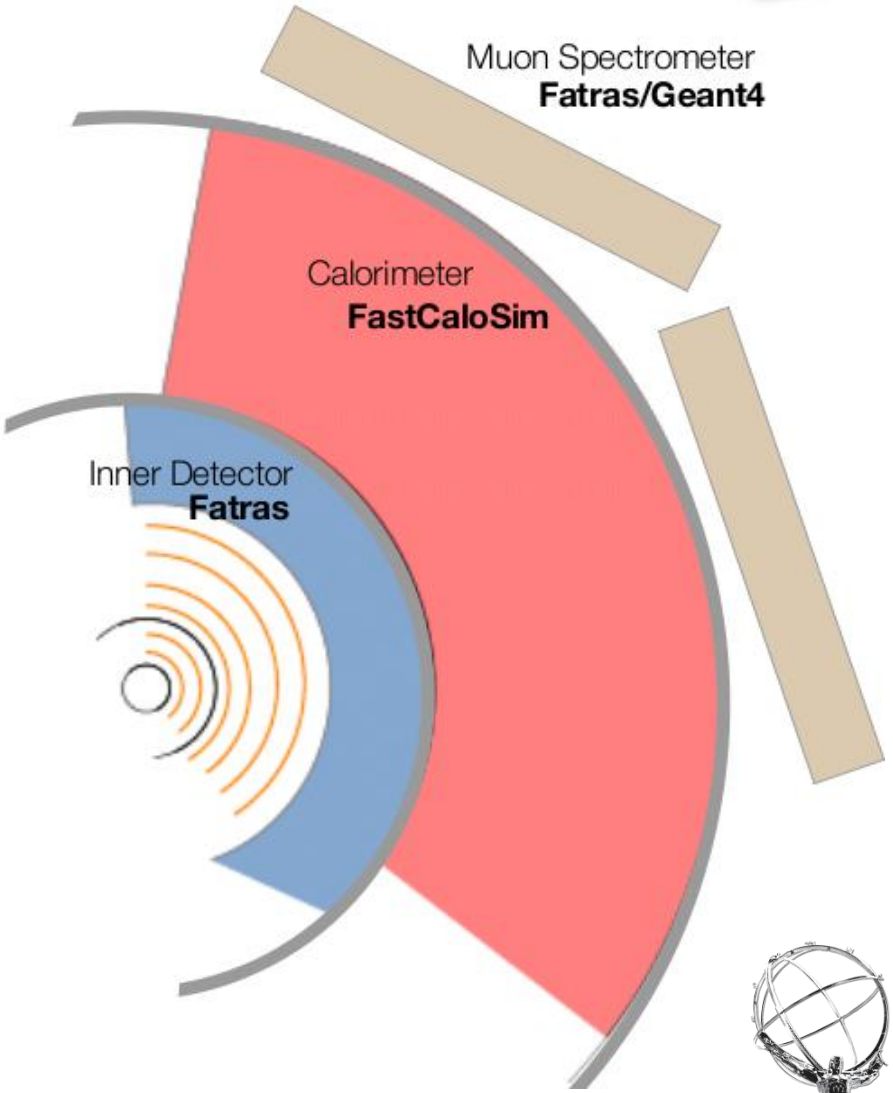
⇒ Replacement of calorimeter simulation with parameterised FastCaloSim

⇒ Replacement of Track simulation with **Fast Track Simulation (Fatras)**

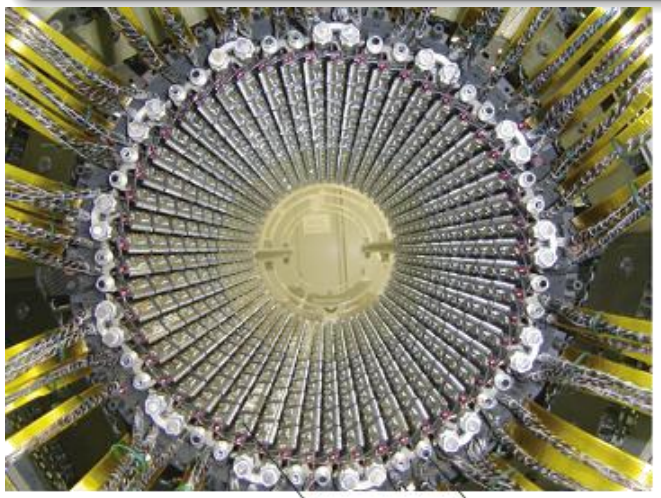
⇒ Relative CPU speed improvement w.r.t full Geant4 simulation:

> 100

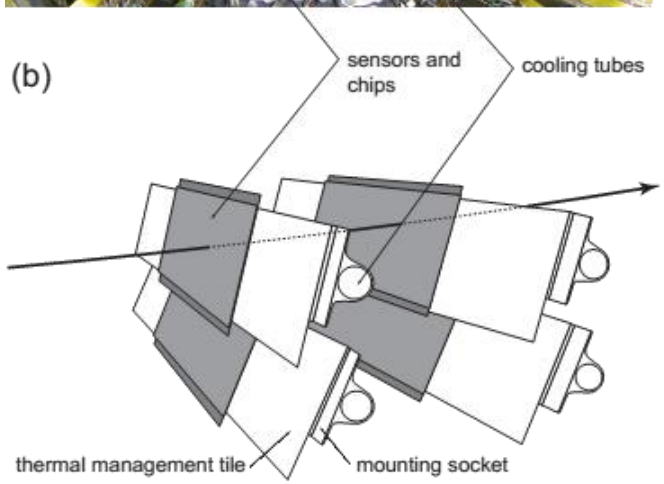
- Drawbacks:
  - simplifications of material integration (less tail effects in resolutions)

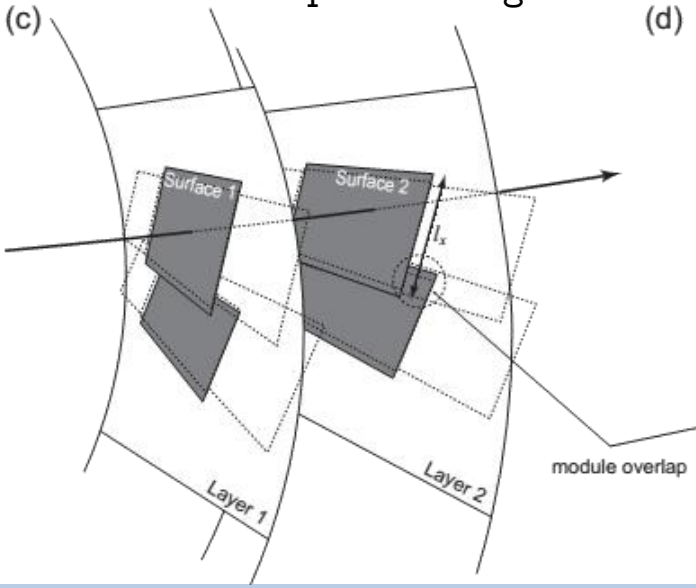


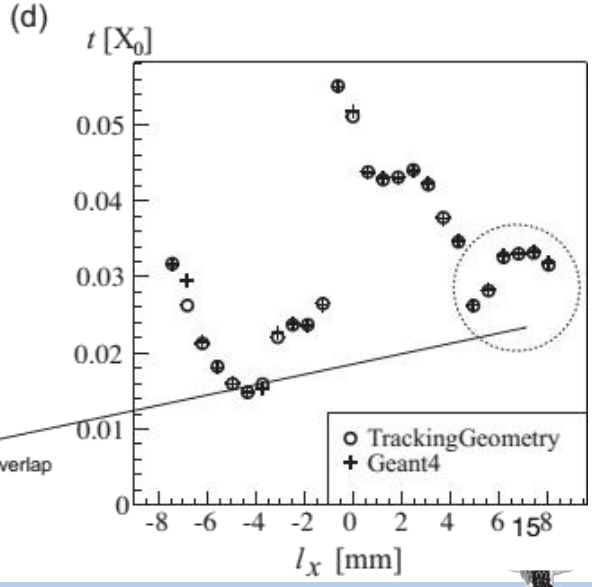
Fatras - Tracking Geometry with navigation



- ATLAS TrackingGeometry
  - Inner Detector & Muon spectrometer:
    - 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

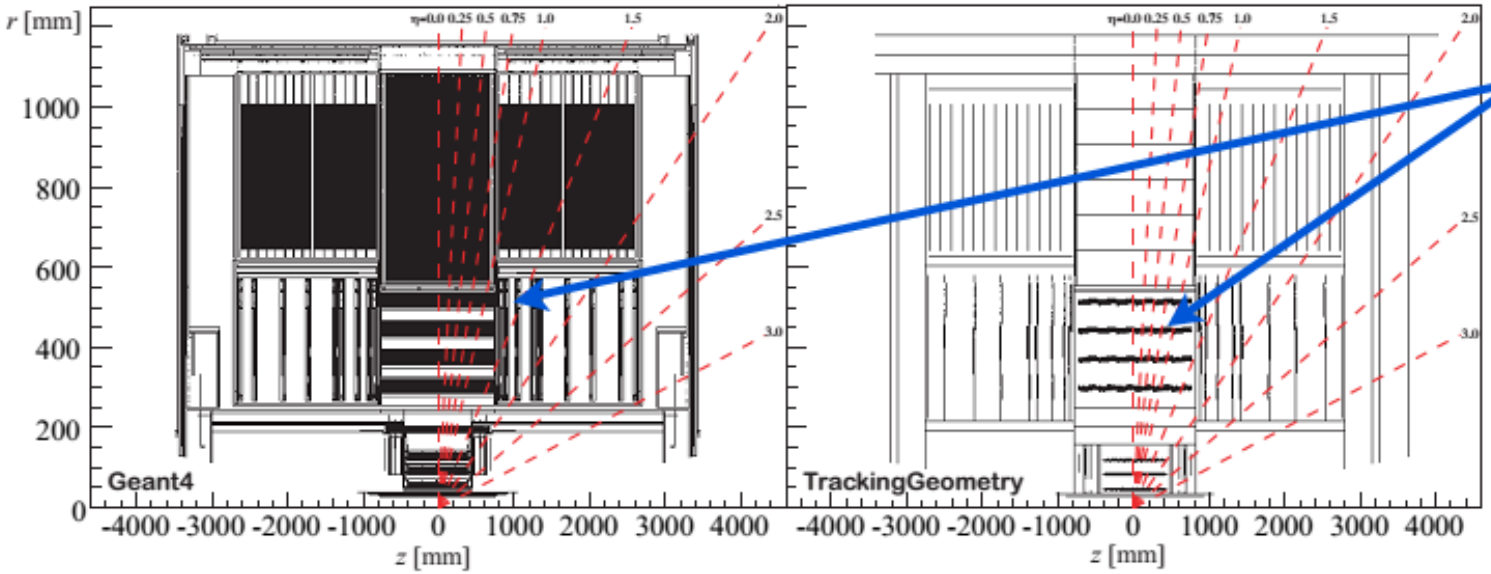






Fatras - Tracking Geometry with navigation

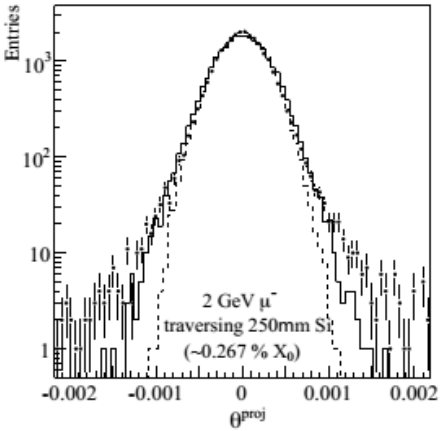
Example Inner Detector:



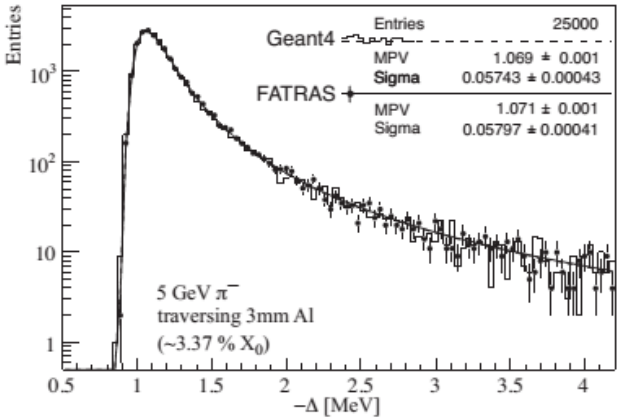
Fatras - Simplified material effects

Parameterisation of material interactions:

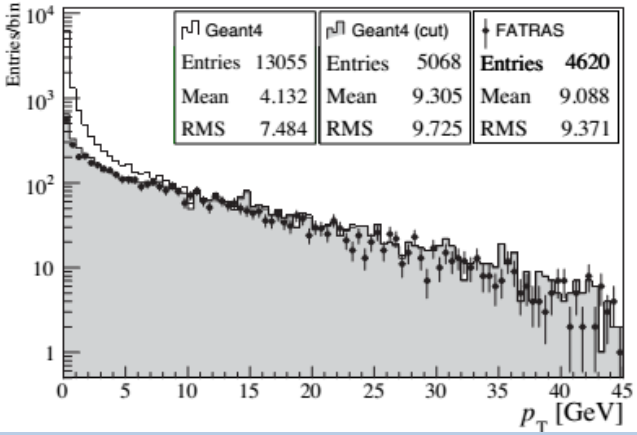
(a) multiple scattering



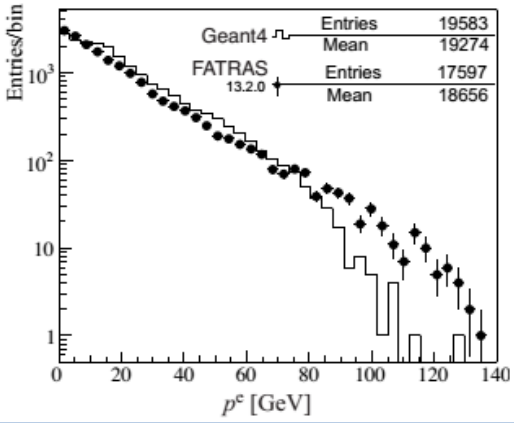
(b) ionisation energy loss



(c) brem photon radiation

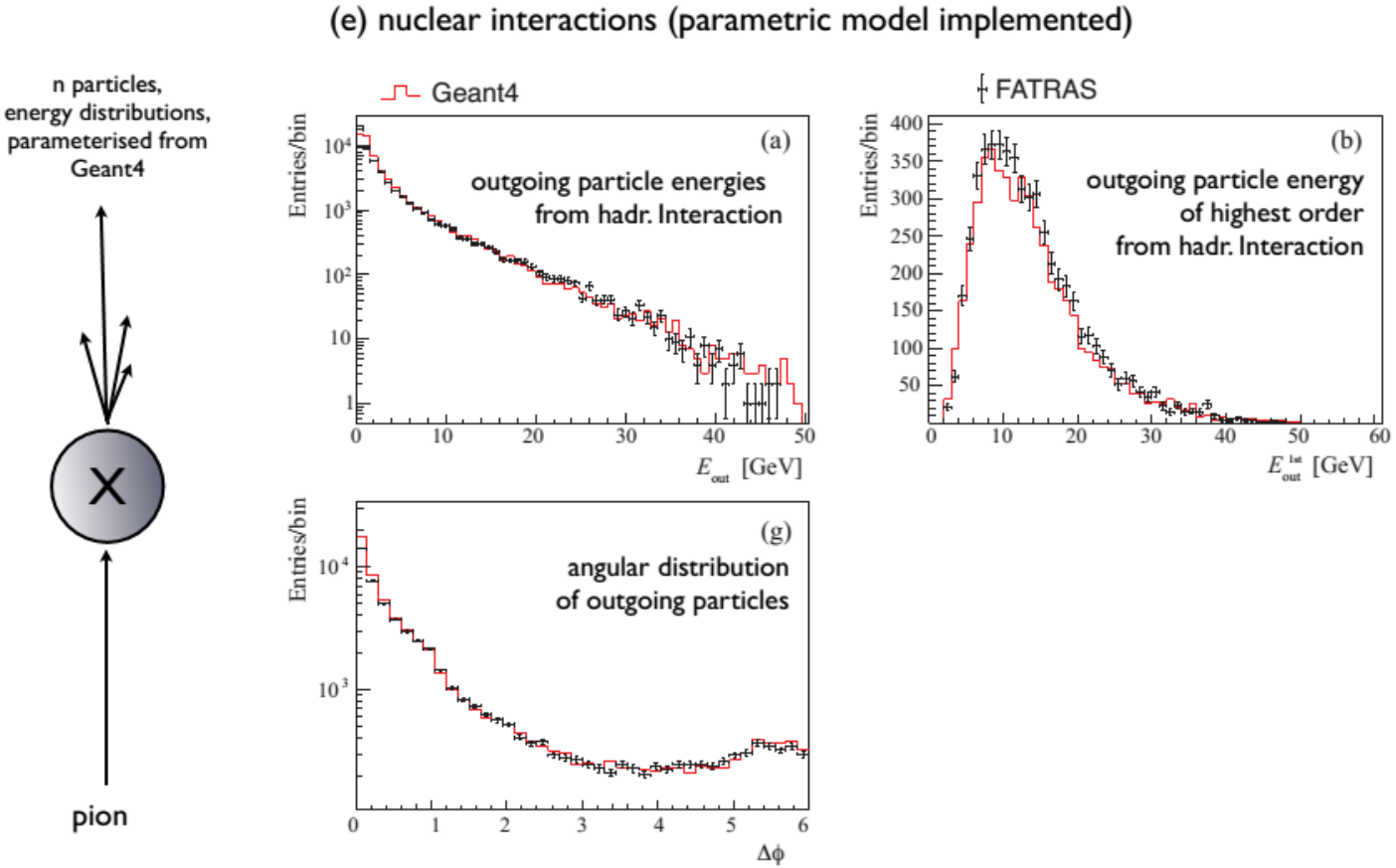


(d) brem photon conversion



Fatras - Simplified material effects

Parameterisation of material interactions:



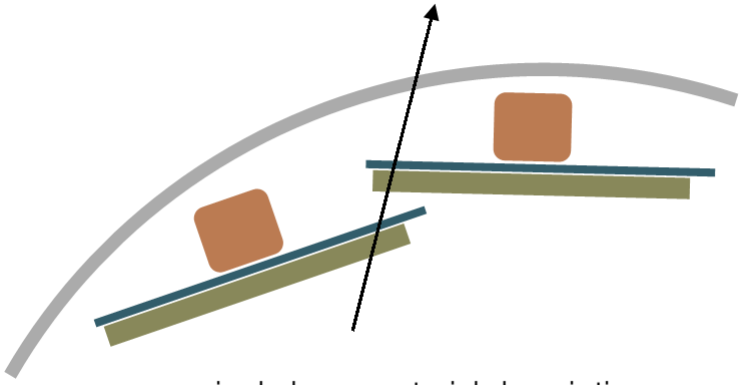
- Currently testing a Geant4 based hadronic interaction processor

Fatras for Upgrade

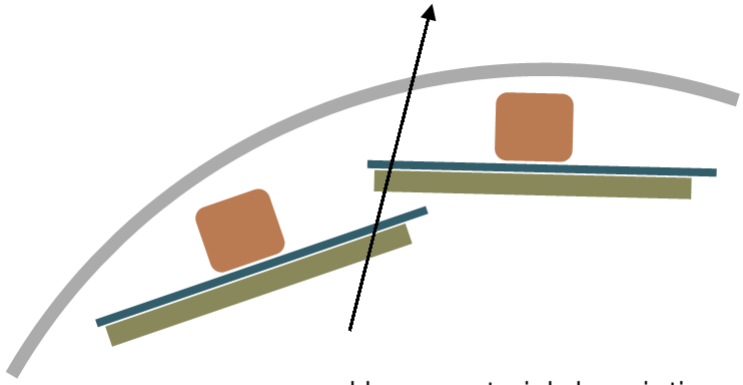
- Fatras being currently extended for upgrade
  - Idea to have a flexible simulation setup that allows for quick layout iterations
  - More realistic material description
    - More realistic hadronic interaction introducing a Geant4 based hadronic interaction processor

New ID extrapolation & geometry goodies

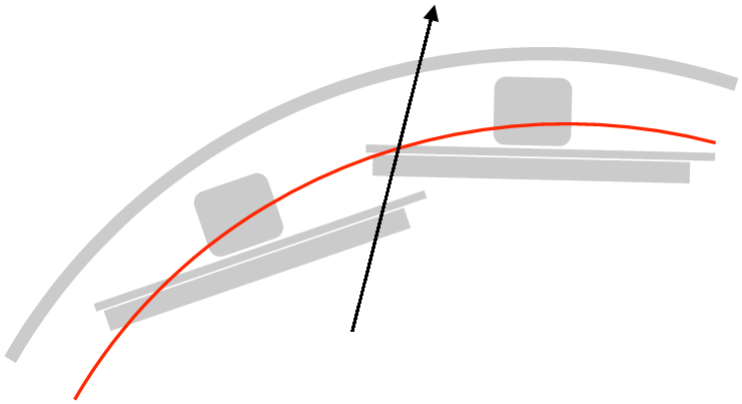
Allow detector surfaces to have material, opens a new way of material integration:

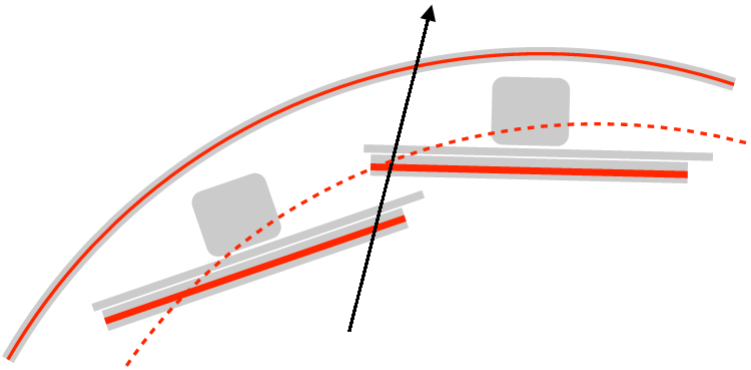


single layer material description



compound layer material description

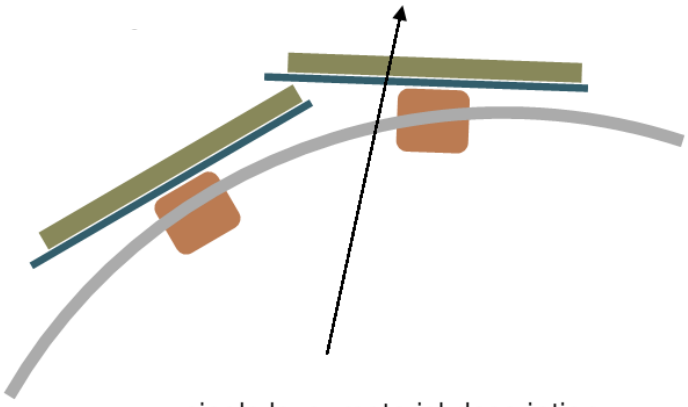




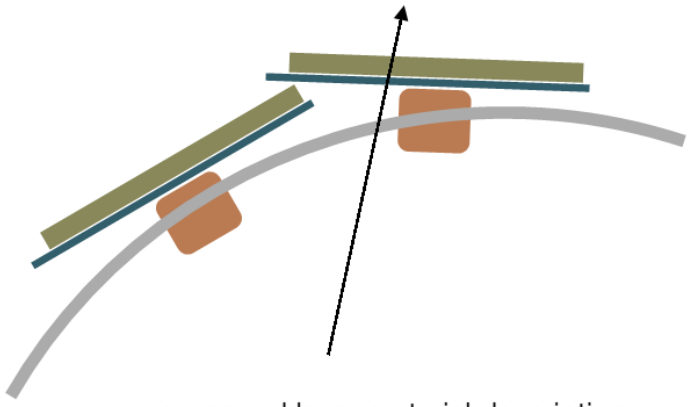
designed for upgrade & GeoComponents

New ID extrapolation & geometry goodies

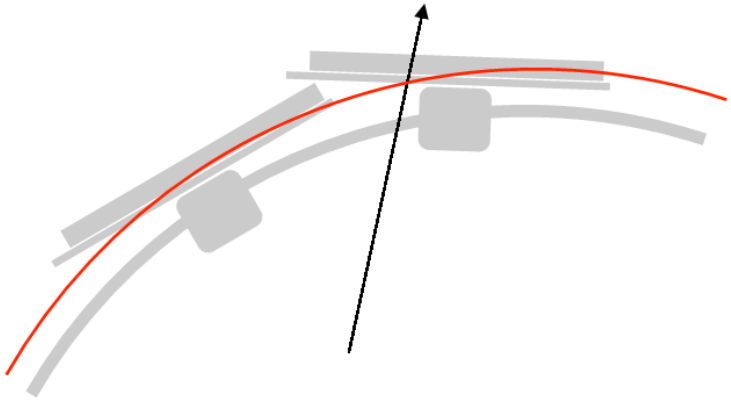
Allow detector surfaces to have material, opens a new way of material integration:

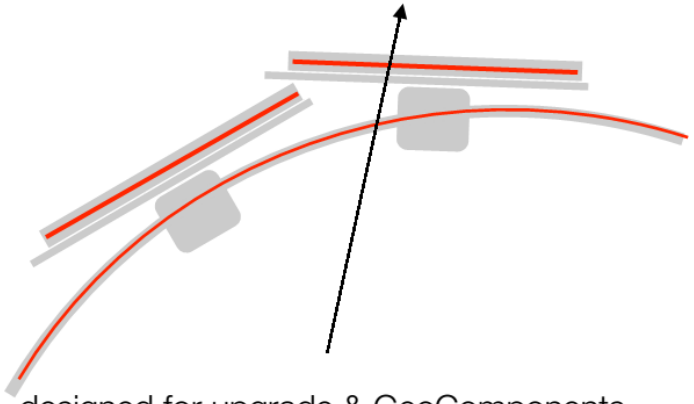


single layer material description



compound layer material description





designed for upgrade & GeoComponents

Change of the building structure

- ATLAS TrackingGeometry can be built using a set of simple input parameters to build tracker layout

iFatras::
PlanarDetectorElement

smallest entity

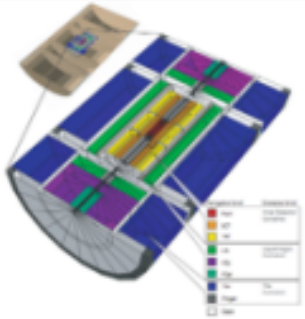
defines size of a detecting element
readout segmentation & resolution

input: python

Trk::Layer

detector elements are used to build Trk::Layer objects
described by modules in phi, eta, overlaps

input: python



layers are built to a TrackingGeometry

so far, standard ATLAS TrackingGeometry builders
(may need some updates for e.g. Alpine layout)

input: python

ATLAS Pixel & SCT Detector

```
if buildCustomPixel:
    # PIXEL building
    from ISF_FatrasDetDescrTools.ISF_FatrasDetDescrToolsConf import iFatras__PlanarDetLayerBuilder
    PixelLayerBuilder = iFatras__PlanarDetLayerBuilder(name=namePrefix+'PixelLayerBuilder')
    PixelLayerBuilder.PixelCase                  = True
    PixelLayerBuilder.Identification       = 'Pixel'
    PixelLayerBuilder.CheckGeo = False
    PixelLayerBuilder.InputLayerMaterialProvider = ISF_InputLayerMaterialProvider

    # Assign custom material
    PixelLayerBuilder.BarrelLayerBinsZ     = TrkDetFlags.PixelBarrelLayerMaterialBinsZ()
    PixelLayerBuilder.BarrelLayerBinsPhi   = TrkDetFlags.PixelBarrelLayerMaterialBinsPhi()
    PixelLayerBuilder.EndcapLayerBinsR     = TrkDetFlags.PixelEndcapLayerMaterialBinsR()
    PixelLayerBuilder.EndcapLayerBinsPhi   = TrkDetFlags.PixelEndcapLayerMaterialBinsPhi()
    PixelLayerBuilder.CustomMaterial          = False
    PixelLayerBuilder.CustomMaterialThickness = 0.250
    PixelLayerBuilder.CustomMaterialX0        = 8.333
    PixelLayerBuilder.CustomMaterialL0        = 100
    PixelLayerBuilder.CustomMaterialA         = 14
    PixelLayerBuilder.CustomMaterialZ         = 28.0855
    PixelLayerBuilder.CustomMaterialRho       = 0.00233

    # BARREL
    PixelLayerBuilder.BarrelLayers = 3
    PixelLayerBuilder.LayersZsectors = [ 13, 13, 13]
    PixelLayerBuilder.LayerPhiSectors = [ 22, 38, 52 ]
    PixelLayerBuilder.LayerTilt = [ -20.0, -20.0, -20.0 ] #degree
    PixelLayerBuilder.LayerMinPhi = [ -180.0, -180.0, -180.0 ] #degree
    PixelLayerBuilder.LayerMaxPhi = [ 180.0, 180.0, 180.0 ] #degree
    PixelLayerBuilder.LayerMinZ = [ -400.5, -400.5, -400.5 ]
    PixelLayerBuilder.LayerMaxZ = [ 400.5, 400.5, 400.5 ]
    PixelLayerBuilder.LayerRadius = [ 50.5, 88.5, 122.5]
    PixelLayerBuilder.LayerThickness = [0.250, 0.250, 0.250]
    PixelLayerBuilder.LayerLengthY = [ 60.8, 60.8, 60.8 ]
    PixelLayerBuilder.LayerLengthXmin = [ 16.4 , 16.4 , 16.4]
    PixelLayerBuilder.LayerPitchX = [ 0.010, 0.010, 0.010 ]
    PixelLayerBuilder.LayerPitchY = [ 0.055, 0.055, 0.055 ]
    PixelLayerBuilder.LayerRotation = [1., 1., 1.] #degree
    PixelLayerBuilder.AdditionalLayerRadius = []

    # ENDCAPS
    PixelLayerBuilder.EndcapDiscs = 3
    PixelLayerBuilder.DiscPhiSectors = [[48], [48], [48]]
    PixelLayerBuilder.DiscZpos = [-650.0, -580.0, -495.0, 495.0, 580.0, 650.0]
    PixelLayerBuilder.DiscRingMinR = [[88.8], [88.8], [88.8]]
    PixelLayerBuilder.DiscRingMaxR = [[149.6], [149.6], [149.6]]
    PixelLayerBuilder.DiscMinPhi = [[-180.0], [-180.0], [-180.0]]
    PixelLayerBuilder.DiscMaxPhi = [ [180.0],  [180.0],  [180.0]]
    PixelLayerBuilder.DiscThickness = [0.250, 0.250, 0.250]
    PixelLayerBuilder.DiscLengthY = [[60.8], [60.8], [60.8]]
    PixelLayerBuilder.DiscLengthXmin = [[16.4], [16.4], [16.4]]
    PixelLayerBuilder.DiscPitchX = [[0.010], [0.010], [0.010]]
    PixelLayerBuilder.DiscPitchY = [[0.055], [0.055], [0.055]]
    PixelLayerBuilder.DiscSeparation = [[0.500], [0.500], [0.500]]
    PixelLayerBuilder.AdditionalDiscZpos = [ -1900. , 1900. ]
```

```
if buildCustomSCT:
    # SCT building
    from ISF_FatrasDetDescrTools.ISF_FatrasDetDescrToolsConf import iFatras__PlanarDetLayerBuilder
    SCT_LayerBuilder = iFatras__PlanarDetLayerBuilder(name=namePrefix+'SCT_LayerBuilder')
    SCT_LayerBuilder.PixelCase                  = False
    SCT_LayerBuilder.Identification             = 'SCT'
    SCT_LayerBuilder.CheckGeo                   = False
    SCT_LayerBuilder.InputLayerMaterialProvider = ISF_InputLayerMaterialProvider
    SCT_LayerBuilder.SiDetManagerLocation       = 'SCT'
    # Assign custom material
    SCT_LayerBuilder.BarrelLayerBinsZ           = TrkDetFlags.SCT_BarrelLayerMaterialBinsZ()
    SCT_LayerBuilder.BarrelLayerBinsPhi         = TrkDetFlags.SCT_BarrelLayerMaterialBinsPhi()
    SCT_LayerBuilder.EndcapLayerBinsR           = TrkDetFlags.SCT_EndcapLayerMaterialBinsR()
    SCT_LayerBuilder.EndcapLayerBinsPhi         = TrkDetFlags.SCT_EndcapLayerMaterialBinsPhi()
    SCT_LayerBuilder.CustomMaterial             = False
    SCT_LayerBuilder.CustomMaterialThickness    = 0.250
    SCT_LayerBuilder.CustomMaterialX0           = 8.333
    SCT_LayerBuilder.CustomMaterialL0           = 100
    SCT_LayerBuilder.CustomMaterialA            = 14
    SCT_LayerBuilder.CustomMaterialZ            = 28.0855
    SCT_LayerBuilder.CustomMaterialRho          = 0.00233

    # BARREL
    SCT_LayerBuilder.BarrelLayers = 4
    SCT_LayerBuilder.LayerSCTlike = True
    SCT_LayerBuilder.LayersZsectors = [12, 12, 12, 12]
    SCT_LayerBuilder.LayerPhiSectors = [32, 40, 48, 56]
    SCT_LayerBuilder.LayerTilt = [11.0, 11.0, 11.25, 11.25] #degree
    SCT_LayerBuilder.LayerMinPhi = [ -180.0, -180.0, -180.0, -180.0] #degree
    SCT_LayerBuilder.LayerMaxPhi = [ 180.0, 180.0, 180.0, 180.0] #degree
    SCT_LayerBuilder.LayerMinZ = [ -742.095, -742.095, -742.095, -742.095]
    SCT_LayerBuilder.LayerMaxZ = [ 742.095, 742.095, 742.095, 742.095]
    SCT_LayerBuilder.LayerRadius = [ 299., 371., 443., 514.]
    SCT_LayerBuilder.LayerSeparation = [ 3., 3., 3., 3.]
    SCT_LayerBuilder.LayerThickness =  [0.2850, 0.2850, 0.2850, 0.2850]
    SCT_LayerBuilder.LayerLengthY = [ 126.09, 126.09, 126.09, 126.09]
    SCT_LayerBuilder.LayerLengthXmin = [ 61.44 , 61.44 , 61.44 , 61.44 ]
    SCT_LayerBuilder.LayerPitchX = [ 0.010, 0.010, 0.010, 0.010 ]
    SCT_LayerBuilder.LayerPitchY = [ 0.055, 0.055, 0.055, 0.055 ]
    SCT_LayerBuilder.LayerRotation = [0., 0., 0., 0.] #degree
    SCT_LayerBuilder.LayerStereo = [-1.15, -1.15, -1.15, -1.15]
    SCT_LayerBuilder.LayerStereoSeparation = [1., 1., 1., 1.]
    SCT_LayerBuilder.AdditionalLayerRadius = []

    #ENDCAPS
    SCT_LayerBuilder.EndcapDiscs = 9
    SCT_LayerBuilder.DiscSCTlike = True
    # from the smallest ring to the biggest
    SCT_LayerBuilder.DiscPhiSectors = [[40, 52], [40, 40, 52], [40, 40, 52], [40, 40, 52], [40, 40, 52], [40, 40, 52], [40, 52], [40, 52], [48]]
    SCT_LayerBuilder.DiscZpos = [-2735.45, -2520.25, -2130.45, -1786.65, -1415.95, -1315.15, -1106.75, -949.25, -869.05,
                                 869.05, 949.25, 1106.75, 1315.15, 1415.95, 1786.65, 2130.45, 2520.25, 2735.45]
    SCT_LayerBuilder.DiscRingMinR = [[337.6, 438.77], [275.0, 337.6, 438.77], [275.0, 337.6, 438.77], [275.0, 337.6, 438.77], [275.0, 337.6, 438.77], [275.0, 337.6,
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    SCT_LayerBuilder.DiscRingMaxR = [[455.3, 560.0], [334.1, 455.3, 560.0], [334.1, 455.3, 560.0], [334.1, 455.3, 560.0], [334.1, 455.3, 560.0], [334.1, 455.3, 560.0],
[334.1, 455.3, 560.0], [455.3, 560.0], [455.3, 560.0], [560.0]]
    SCT_LayerBuilder.DiscMinPhi = [[-180.0, -180.0], [-180.0, -180.0, -180], [-180.0, -180.0, -180], [-180.0, -180.0, -180], [-180.0, -180.0,
-180], [-180.0, -180.0, -180], [-180.0, -180.0], [-180.0, -180.0], [-180.0]]
    SCT_LayerBuilder.DiscMaxPhi = [[180.0, 180.0], [180.0, 180.0, 180], [180.0, 180.0, 180], [180.0, 180.0, 180], [180.0, 180.0,
180.0, 180], [180.0, 180.0], [180.0, 180.0], [180.0]]
    SCT_LayerBuilder.DiscThickness = [0.2850, 0.2850, 0.2850, 0.2850, 0.2850, 0.2850, 0.2850, 0.2850, 0.2850]
    SCT_LayerBuilder.DiscLengthY = [[117.7, 117.7], [117.7, 117.7, 117.7], [117.7, 117.7, 117.7], [117.7, 117.7, 117.7], [117.7, 117.7, 117.7],
[117.7, 117.7, 117.7], [117.7, 117.7], [117.7, 117.7], [117.7]]
    SCT_LayerBuilder.DiscLengthXmin = [[83.78, 83.78], [83.78, 83.78, 83.78], [83.78, 83.78, 83.78], [83.78, 83.78, 83.78], [83.78, 83.78,
83.78], [83.78, 83.78, 83.78], [83.78, 83.78], [83.78, 83.78], [83.78]]
    SCT_LayerBuilder.DiscLengthXmax = [[92.53, 92.53], [92.53, 92.53, 92.53], [92.53, 92.53, 92.53], [92.53, 92.53, 92.53], [92.53, 92.53,
92.53], [92.53, 92.53, 92.53], [92.53, 92.53], [92.53, 92.53], [92.53]]
    SCT_LayerBuilder.DiscPitchX = [[0.010, 0.010], [0.010, 0.010, 0.010], [0.010, 0.010, 0.010], [0.010, 0.010, 0.010], [0.010, 0.010, 0.010],
[0.010, 0.010, 0.010], [0.010, 0.010], [0.010, 0.010], [0.010]]
    SCT_LayerBuilder.DiscPitchY = [[0.055, 0.055], [0.055, 0.055, 0.055], [0.055, 0.055, 0.055], [0.055, 0.055, 0.055], [0.055, 0.055, 0.055],
[0.055, 0.055, 0.055], [0.055, 0.055], [0.055, 0.055], [0.055]]
    SCT_LayerBuilder.DiscSeparation = [[5., 5.], [5., 5., 5.], [5., 5., 5.], [5., 5., 5.], [5., 5., 5.], [5., 5., 5.], [5., 5.], [5., 5.], [5.]]
    SCT_LayerBuilder.RingDisplacement = [[15.25, 15.25], [15.25, 15.25, 15.25], [15.25, 15.25, 15.25], [15.25, 15.25, 15.25], [15.25, 15.25, 15.25],
15.25], [15.25, 15.25, 15.25], [15.25, 15.25], [15.25, 15.25], [0.]]
    SCT_LayerBuilder.DiscStereo = [[2.3, 2.3], [2.3, 2.3, 2.3], [2.3, 2.3, 2.3], [2.3, 2.3, 2.3], [2.3, 2.3, 2.3], [2.3, 2.3, 2.3], [2.3, 2.3,
2.3], [2.3, 2.3], [2.3, 2.3], [2.3]]
    SCT_LayerBuilder.DiscStereoSeparation = [[1., 1.], [1., 1., 1.], [1., 1., 1.], [1., 1., 1.], [1., 1., 1.], [1., 1., 1.], [1., 1.], [1., 1.],
[1.]]
    SCT_LayerBuilder.AdditionalDiscZpos = [ -2850 , 2850 ]
```
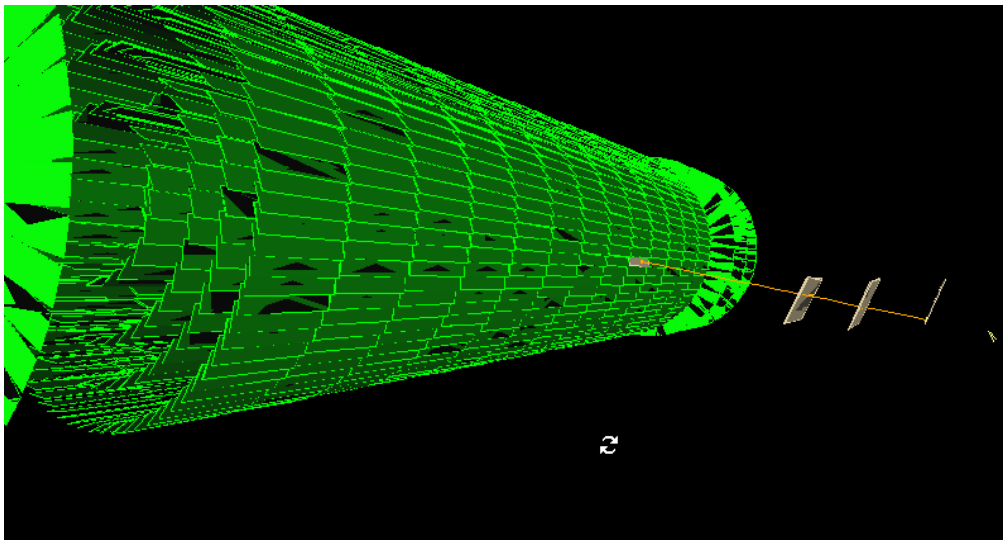
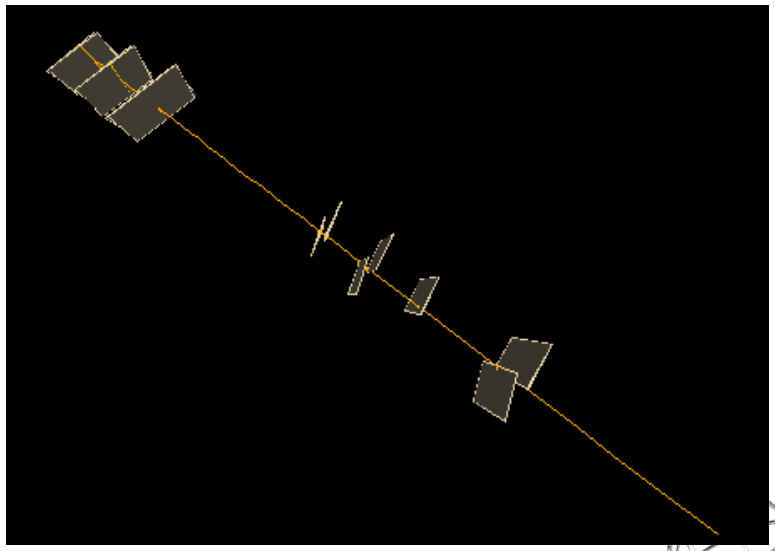

Simulation → Digitisation → Recontruction





Conclusions

- Working on Fast Track Simulation (Fatras) for upgrade
- Validation of the tool reproducing ATLAS and ATLAS+IBL results
- Study new ATLAS Inner Tracker layouts for Phase-II upgrade
  - Very forward detectors
  - Fifth pixel layer (and maybe sixth)
  - …